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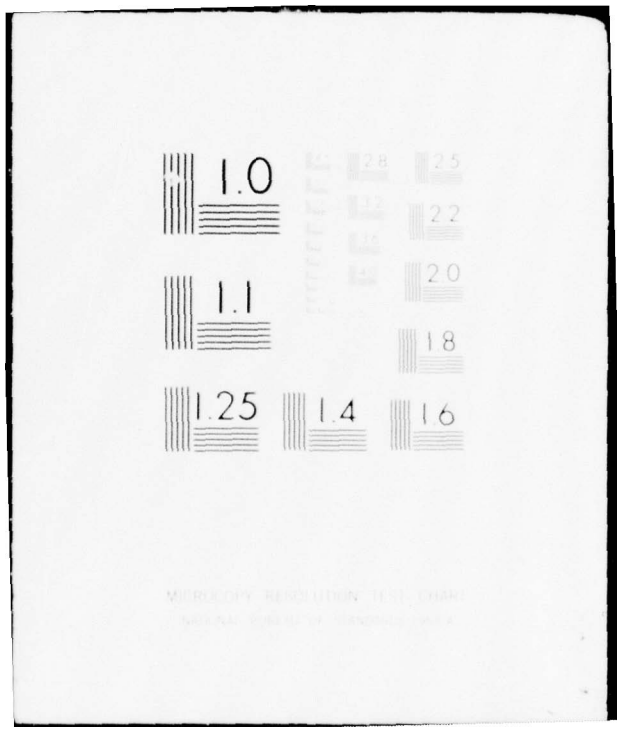
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LOWER COLORADO REGION
Comprehensive Framework Study

MAIN REPORT
JUNE 1971

PREPARED BY:

LOWER COLORADO REGION STATE – FEDERAL
INTERAGENCY GROUP FOR THE
PACIFIC SOUTHWEST INTERAGENCY COMMITTEE

LOWER COLORADO REGION – Main Report – June 1971

APPENDIXES TO THE MAIN REPORT

LOWER COLORADO REGION

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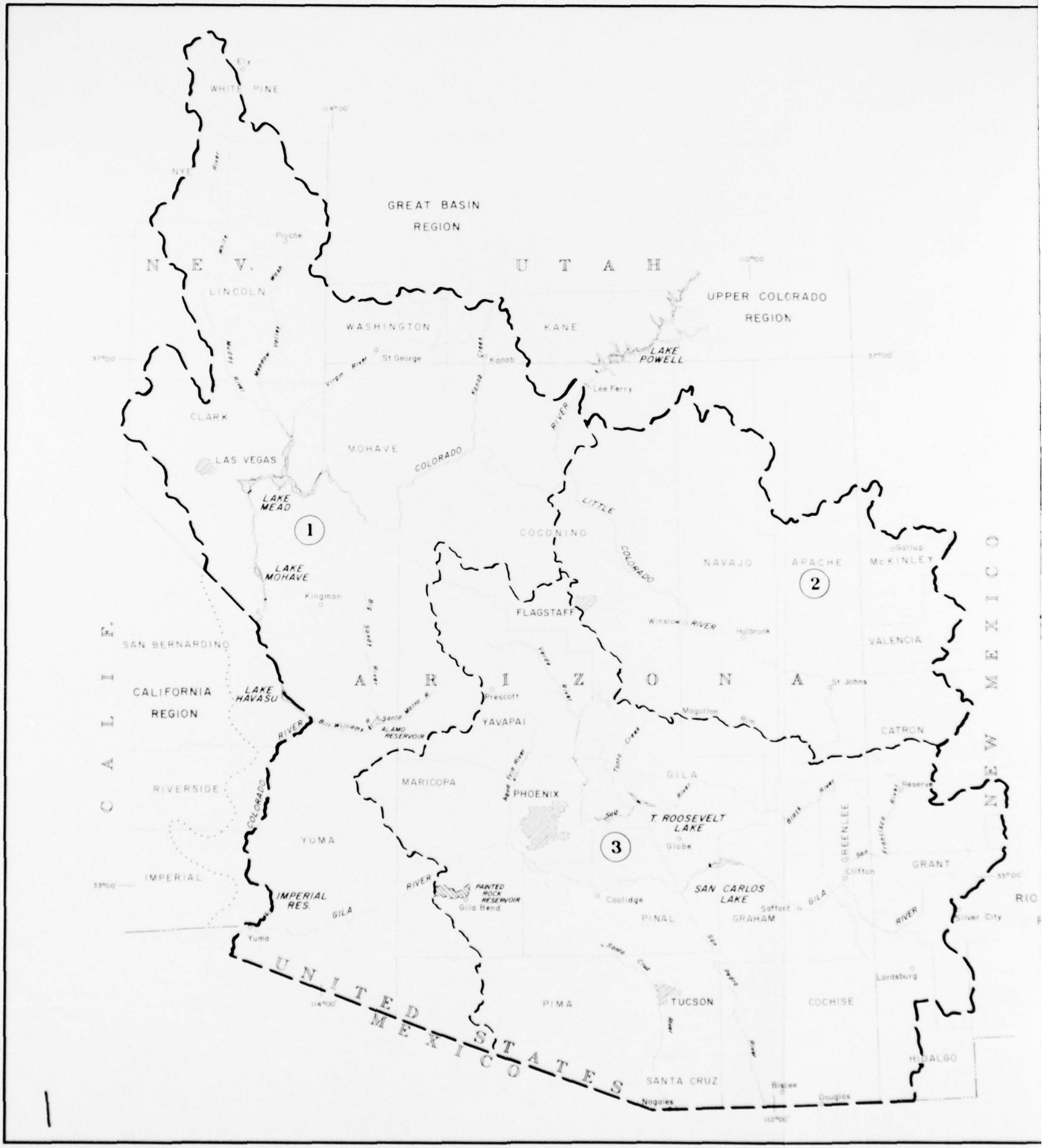
LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY,

MAIN REPORT.

This report of the Lower Colorado Region Framework Study State-Federal Interagency Group was prepared at field level and presents a framework program for the development and management of the water and related land resources of the Lower Colorado Region. This report is subject to review by the interested Federal agencies at the departmental level, by the Governors of the affected States, and by the Water Resources Council prior to its transmittal to the Congress for its consideration.

While the comprehensive framework plan presented herein is the result of a coordinated effort by participants from various Federal and State agencies involved in the Study, it does not necessarily reflect the singular viewpoint or policy of any particular agency or state. The type and need for future developments may change appreciably from the framework plan as a result of differing assumptions, methodology, and objectives used in water and land use plans prepared by the State and/or Federal agencies.

June 1971


GREAT BASIN REGION
UPPER COLORADO REGION
CALIFORNIA REGION
N E V.
U T A H
A R I Z O N A
C A L I F.
N E W M E X I C O
UNITED STATES
MEXICO
WHITE PINE
NYE
LINCOLN
CLARK
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
CATRON
YAVAPAI
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GILA
GREENLEE
GRANT
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COCHISE
SANTA CRUZ
HIDALGO
SAN BERNARDINO
RIVERSIDE
IMPERIAL
Ely
Pioche
St George
Kanab
Lee Ferry
LAS VEGAS
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
LAKE POWELL
Kingman
FLAGSTAFF
Winslow
Holbrook
Gallup
St Johns
Prescott
PHOENIX
T. ROOSEVELT LAKE
Globe
SAN CARLOS LAKE
Coolidge
Safford
Clifton
Silver City
Lordsburg
Reserve
TUCSON
Nogales
Bisbee
Douglas
Yuma
Gila Bend
IMPERIAL RES.
PAINTED ROCK RESERVOIR
ALAMO RESERVOIR
COLORADO RIVER
LITTLE COLORADO RIVER
GILA RIVER
Virgin River
Kanab Creek
Bill Williams R.
Santa Maria R.
Verde River
Agua Fria River
Tonto Creek
Salt River
Black River
San Francisco River
San Pedro River
Santa Cruz River
Mogollon Rim
White River
Meadow Valley Wash
Muddy River
1
2
3
114°00'
110°00'
37°00'
33°00'

INDEX MAP

UPPER COLORADO REGION

LAKE POWELL

Lee Ferry

LITTLE COLORADO

NAVAJO

APACHE

MCKINLEY

Gallup

2

Winslow

RIVER

Holbrook

VALENCIA

A R I Z O N A

St Johns

Magollon

CATRON

NEW MEXICO

GILA

T ROOSEVELT LAKE

Globe

3

GREENLEE

Clifton

GRANT

SAN CARLOS LAKE

Coolidge

Safford

GILA

RIVER

Silver City

RIO GRANDE REGION

PINAL

GRAHAM

Lordsburg

TUCSON

COCHISE

HIDALGO

SANTA CRUZ

Nogales

Bisbee

Douglas

EXPLANATION

- Lower Colorado Region boundary
- Subregion boundary
- (1) Lower Main Stem
- (2) Little Colorado
- (3) Gila
- Lower Colorado Basin boundary
- Existing dam and reservoir
- Existing dam and intermittent lake

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION - HYDROLOGIC

GENERAL LOCATION MAP

MAP NO. 1019-314-45

50 0 50 100 150

SCALE OF MILES

REV. 3-71

MAIN REPORT

prepared by the

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of the

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for the

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LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDIES

SUMMARY OF FINDINGS

This report presents the results of comprehensive investigations of water and related land resources of the Lower Colorado Region. It provides appraisals of natural resources and their geographic distribution, projections of future requirements, associated problems and needs, and presents a framework program for the development and management of the water and related land resources of the Region to the year 2020, with intermediate objectives to the years 1980 and 2000. A schedule of implementation is presented, together with a general estimate of costs, for the program.

The Lower Colorado Region, 141,137 square miles in extent, includes most of Arizona, and parts of Nevada, New Mexico, and Utah, and comprises nearly 5 percent of the contiguous United States. The population is concentrated principally in south central Arizona and southern Nevada. The remainder of the Region's population is located in small, widely scattered communities. Much of the area is uninhabited.

Except for the availability of water supply, the Region is bountifully provided with resources, space, and general environment which will support future growth. Probably the most stimulating single factor on the growth of the Region is the climate which permits activities such as irrigated agriculture, construction, entertainment, tourism, and outdoor recreation during the entire year.

Economic Projections and Activities

Inventories and appraisals of resources and development of the Lower Colorado Region were prepared for a base year, 1965, and a 55-year projection time frame with three target years, 1980, 2000, and 2020. National interregional projections, which equated national demand and supply together with consistent regional projections based upon historical trends in interregional production relationships, were developed by the Office of Business Economics, U.S. Department of Commerce, and the Economic Research Service, U.S. Department of Agriculture. These projections, referred to as OBE-ERS projections in this study, were based upon specific assumptions. A primary assumption was that the population of the United States will grow at the U.S. Census Series C rate which is substantially below the 1962-65 rate, but above more recent rates. Other basic assumptions are included in this and the other functional appendixes relative to the particular resource aspect being considered.

The OBE-ERS projections for the Region were modified somewhat to more closely reflect regional trends. These "Modified OBE-ERS" projections have been used in development of the Lower Colorado Region comprehensive framework program. A comparison of the Modified OBE-ERS and OBE-ERS projections is included in the latter part of Appendix IV, Economic Base and Projections.

Population is expected to increase nearly 4 times, municipal and industrial water requirements over 6 times, electric energy requirements over 42 times, recreation demand over 6 times, and flood damage will increase nearly 8 times by the year 2020. Personal per capita income in the Region was $2,292, about 90 percent of the national average in 1965, and by year 2020 is projected to almost equal the national average of more than $12,000.

Water Supply

Much of the Region's economy is sustained by utilizing ground-water reserves. In 1965, the depletion rate of these reserves reached 2.5 million acre-feet annually due largely to the lack of facilities for enabling the Region to utilize its share of Colorado River water. The Southern Nevada Water Project, presently under construction, the Central Arizona Project, and the Dixie Project in Utah must be completed at an early date in order for the Region to utilize the remainder of the available renewable water supplies. In the absence of an imported water supply, ground-water overdraft is expected to continue and the regional water deficiency is projected to reach 4.50 million acre-feet annually by year 2020.

Water resource-oriented programs need to be accelerated in the future with respect to both planning and implementation if future requirements are to be satisfied on a timely schedule. The basic long-range objective is augmentation of the Region's water supplies in sufficient increments to meet future water requirements and reduce ground-water overdraft. It is recognized that a program of this magnitude will probably require time, in the order of 20 years, to implement. In the meantime, all possibilities for lessening the effects of the increasing water deficiencies must be explored.

The framework program includes expansion of water conservation and management practices, more intensive water reuse, vegetative management for increased water yields, and treatment of brackish water. Water salvage programs and vegetative management programs for increased water yield are expected to add about 500,000 acre-feet annually to the local water supply by 2020. Further studies are needed to evaluate the potential of untapped ground-water reserves in remote basins which could provide an interim water supply.

Implementation of the long-range program requires early initiation of planning for importing water to the Region. Studies should be included for evaluating the relative merits of all potential means of importation. Implementation of a water import program should be accomplished by year 1990 to provide about 2.25 million acre-feet. This should be increased to 4.15 million acre-feet by year 2020. The initial stage of the importation program would include the national commitment 1/ to relieve the Colorado River Basin States of the Mexican Treaty burden, estimated to be 1.8 million acre-feet annually including associated losses.

Table A-1 provides a summary of the present and projected water requirements and supplies.

Water Quality

Maintenance of an acceptable level of water quality is vital to the economy, environment, and general well-being of the people of the Region. Presently deficient water supplies and the probable cost of future imported water dictate maximum water utilization, including recycling, with little or no allowance for transporting salts or waste loads from the Region. The water quality program includes waste treatment facilities for urban centers, treatment of water from saline sources, and major water reuse facilities. Augmentation of the Colorado River with high quality imported water would also provide major improvement in the quality of this principal water source. Continuing studies of the Region's increasingly complex water quality problems are recommended.

Land Resources and Use

The land resource base of the Region appears to be sufficient in variety and amount to satisfy the projected land use requirements through the year 2020. There will be need to be widespread adoption of the multiple-use principle in order to satisfy the requirements of all uses.

1/ 90th Congress, Public Law 90-537, An Act to Authorize . . . the Colorado River Basin Project . . . , September 1968.

The following tabulation shows the major land use requirements for the period of study:

Use	Requirements - 1,000 Acres			
	1965	1980	2000	2020
Cropland	1,816	1,891	1,905	1,852
Irrigated	(1,785)	(1,863)	(1,882)	(1,833)
Nonirrigated	(31)	(28)	(23)	(19)
Livestock Grazing	76,054	73,739	69,902	65,807
Timber Production	5,458	5,358	5,153	5,044
Urban and Industrial	513	863	1,230	1,564
Outdoor Recreation (designated) 1/	5,542	5,888	6,012	6,146
Wilderness Areas	861	1,458	3,158	3,458
Fish and Wildlife (designated) 1/	3,223	3,546	7,175	15,020
Military	4,126	4,126	4,126	4,126
Transportation and Utilities	660	858	1,030	1,145
Water Yield Improvement	114	289	824	1,229
Flood Control	77	229	289	336
Mineral Production	76	115	156	223

1/ Designated: Lands which are administered primarily for the purpose but not precluding other activities which are compatible.

Land Treatment and Management

Irreversible losses of the Region's land resources must be minimized to preserve a freedom of choice for future resource users. Esthetic and environmental factors were of primary consideration in development of the program. Ideally, the land treatment and management program should harmonize with all water and related land resource development programs required to satisfy present and projected demands within the Region. On an equivalent acreage basis, as of 1965, a total of nearly 7 million acres of cropland, forest land, rangeland, and urban and other lands had received adequate treatment. The program includes treatment of an additional 64 million acres by 2020. In most cases, the same acre will require treatment more than once during the study period because of development of improved methods, or the limited life of the measure or practice installed.

Flood Control

The Region is subject to severe and sudden floods, with some flood damage occurring every year. Almost all land suitable for general development is subject to some degree of flood damage, either from a defined stream or overland flow. The average annual flood damages were estimated at $41 million for 1965 economic and project conditions. With no additional flood control measures after 1965, annual flood damages of $310 million are estimated by the year 2020. Implementation of the flood

control program of structural and nonstructural measures would prevent a large portion of the damages, so that remaining damages of only $68 million annually are estimated by the year 2020. For these remaining damages, there appear to be no feasible solutions.

Irrigation and Drainage

Irrigated land is expected to increase from the 1965 level of 1,315,000 1/ to 1,613,000 acres. Urbanization is expected to remove 204,000 acres from production. The total new irrigation development would be 502,000 acres. The program includes completion of the rehabilitation of existing water conveyance systems for 429,000 acres of presently irrigated lands and new distribution systems to serve 1,075,000 acres, a portion of which is presently irrigated exclusively from ground water. Onfarm water management measures such as land leveling and water control structures are recommended for about 2.2 million acres during the study period. The 2.2 million acres include retreatment of some land because of the expected improved technology and limited life of the structures and measures. These measures would provide better control and more efficient use of irrigation water and/or would reduce costs of irrigation. New drainage facilities are included to serve 188,000 acres.

Municipal and Industrial Water

The rapidly increasing population will require that water for municipal and industrial uses be increased from a 1965 level of 450,000 acre-feet to 2.8 million acre-feet in year 2020. Presently authorized projects will supply 446,000 acre-feet of additional water by 2000. Major urban centers would satisfy their additional water requirements through the importation program and through treatment and recycling of waste water. Smaller communities would fulfill their increasing needs by a variety of means, including additional surface- and ground-water development, desalting of brackish ground water, and by importation.

Mineral Resources

Adequate mineral resources are available to meet the expected increased production, $511 million in 1965 to $1.93 billion in year 2020 (1958 dollars). Water withdrawal requirements would increase from 105,100 to 357,200 acre-feet in this period, while land requirements would increase from 76,000 acres to 223,000 acres. Environmental impacts of the mining and processing of ores will need to be

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1/ Includes only those acres actually irrigated in 1965 plus the acreage double cropped.

minimized, especially with respect to air and water pollution, ecology, and esthetics. Water requirements of the mineral industry may be met by direct diversion of imported water, by upstream developments on the basis that downstream rights would be met by exchange for imported water, or by continued ground-water development where available.

Recreation

Recreation needs of the Region, above available supply, are projected to increase from 144 million recreation days in 1965 to 672 million recreation days in 2020. Under existing legal, institutional, financial, and physical constraints, only about 42 percent of these needs can be met. To satisfy the remaining 58 percent of the needs will require elimination or modification of these constraints and a greater degree of Federal participation.

Water-based recreation needs will climb to 193 million recreation days annually by 2020. Maximum water augmentation, development, and use under the framework plan will supply a part of the water-based recreation needs.

Land acquisition in the amount of 60,000 acres will be required to satisfy the non-Federal recreation needs.

Fish and Wildlife

The annual demand for fishing would increase from a 1965 level of 4.0 million man-days to 26.0 million man-days in year 2020. Multipurpose developments authorized to be constructed by 1980, including the Alamo, Dixie, and Central Arizona Projects, have the potential to provide 1.2 million man-days of fishing annually. Numerous smaller fishing reservoirs are planned for construction by state and Federal agencies and by Indian Tribes to provide 2.0 million man-days of fishing annually by 1980. After 1980, proposed water developments, primarily multipurpose, are expected to provide an additional 1.02 million man-days annually by 2020. To satisfy fishing demands not met by the above developments, the fish and wildlife program provides for additional fishery developments in 1980, 2000, and 2020 that would provide a total of 16.0 million man-days of fishing annually by year 2020.

The demand for hunting is expected to increase from a 1965 level of 1.3 million man-days to 5.1 million man-days annually in 2020. A primary concern in satisfying the demands for wildlife resources is the preservation and improvement of existing habitat. In the Lower Colorado Region, most of the valuable wildlife habitat is on lands administered by public agencies, thus providing significant opportunities for further wildlife development. Satisfying a part of the demand for fish and wildlife resources and achieving optimum multiple-use of public lands are dependent upon improving the existing habitat and accelerating development to increase fish and wildlife production.

Satisfying future demands for fish and wildlife resources will also require that 11.8 million acres of selected areas consisting mostly of public lands be managed to yield maximum fish and wildlife values. The areas would be managed with emphasis directed to the production of fish and wildlife, with appropriate consideration of compatible or complementary uses. The construction of access facilities and numerous wildlife watering facilities is included in the fish and wildlife program.

Electric Power

Electric power requirements are expected to increase by forty-fold between 1965 and 2020. These requirements will need to be met partially by construction of power facilities within the Region and partially by imports from other areas. The regional water requirement for power production would increase from 9,600 acre-feet in 1965 to 434,700 acre-feet by year 2020. The increased water use would be supplied largely by imported water supplies.

Environmental Considerations

The comprehensive nature and interrelationship of environmental problems have recently become widely recognized. The Region's rapid population growth rate, its concentration in only a few locations, the fragile nature of the desert environment, and the extremely limited water supplies require that particular attention be given to the environmental impacts which may occur as the result of development necessary to insure the well-being of the people of the Region. Such considerations have been of paramount concern to planners in nearly every phase of the framework studies. Main items of concern include: preservation of cultural, scenic, and natural values; protection and management of land resources; safeguarding the quality of water supplies; maintenance of the agricultural environment; enhancement of fisheries; and the preservation of wildlife habitat.

Recommendations

It is recommended that the comprehensive framework program for the Lower Colorado Region, as outlined in the report, be adopted as a guide in continuing the planning processes and in formulating specific projects to satisfy water, related land, and environmental development needs.

Summary of Projected Demands and Framework Program

Table A-2 summarizes the Region's gross demands for water-related functions and services. Table A-3 summarizes the regional framework program for the development of water and related land resources needed to satisfy projected requirements, and Table A-4 shows the needs unmet by the framework program.

Table A-1
Summary of Water Requirements and Supply
1965-2020

	1965	Total Annual Demand 1980	2000	2020
Water Requirements				
Withdrawals (1,000 Acre-Feet)				
Reservoir Evaporation 1/	230	286	328	359
Municipal and Industrial	450	863	1,703	2,778
Irrigation	9,138	9,429	8,496	8,405
Recreation	11	21	41	70
Fish and Wildlife	196	214	325	556
Electric Power Cooling	10	37	106	435
Mining	105	176	264	357
Total	10,140	11,026	11,263	12,960
Depletions (1,000 Acre-Feet)				
Reservoir Evaporation 1/	230	286	328	359
Municipal and Industrial	198	358	677	1,149
Irrigation	4,626	5,326	5,312	5,381
Recreation	4	7	14	24
Fish and Wildlife	110	142	232	405
Electric Power Cooling	10	37	107	435
Mining	52	89	135	185
Losses Associated with Recycling and Reuse	600	640	460	580
Total	5,829	6,885	7,265	8,518
Water Supply Without Augmentation (Unit: Million Acre-Feet)				
Colorado River Water Available for Use in Lower Colorado Region	2.63	2.25	1.33	0.90
Local Water Supply	3.12	3.12	3.12	3.12
Total Supply Available for Use in the Lower Colorado Region 2/	5.75	5.37	4.45	4.02
Lower Colorado Region Depletion Requirements	5.83	6.88	7.26	8.52
Regional Water Deficiency 3/	0.08	1.51	2.81	4.50

Table A-1 (Continued)
Summary of Water Requirements and Supply

	1965	Total Annual Demand 1980	2000	2020
Water Supply with Augmentation (Unit: Million Acre-Feet)				
Colorado River Available for Use in Lower Colorado Region	2.63	2.25	1.33	0.90
National Obligation to Mexican Water Treaty 4/	--	--	1.80 3/	1.80 3/
Local Water Supply	3.12	3.12	3.12	3.12
Total Supply Available for Use in Lower Colorado Region 2/	5.75	5.37	6.25	5.82
Lower Colorado Region Depletion Requirements	5.83	6.88	7.26	8.52
Regional Water Deficiency 3/	0.08	1.51	1.01	2.70
Regional Augmentation 5/	___	0.03	0.57	2.53
Remaining Deficiency 6/	0.08	1.48	0.44	0.17

1/ Excludes mainstream Colorado River reservoir evaporation accounted for in the determination of availability of Colorado River water.

2/ Excluding ground-water overdraft.

3/ Lack of facilities prevented utilization of the Region's full share of Colorado River water resulting in a ground-water overdraft of about 2.5 million acre-feet. In the future to limit the water supply deficiency to that tabulated would require: distribution of the available supply to areas of shortage, total utilization of the resource including recycling,and that no allowance be made for transporting salts from the Region.

4/ Consists of 1.5 million acre-feet per annum for delivery to Mexico plus an estimated 0.3 million acre-feet associated losses. In accordance with Public Law 90-537, Section 202, "The Congress declares that the satisfaction of the requirements of the Mexican Water Treaty from the Colorado River constitutes a national obligation which shall be the first obligation of any water augmentation project planned pursuant to Section 201 of this Act and authorized by Congress."

5/ As recommended in the Lower Colorado Region framework program.

6/ To be supplied by ground-water overdraft.

Table A-2
Gross Needs for Water Related Functions and Services

	1965 Base	Total Annual Need		
		1980	2000	2020
Flood Damage Prevention ($ Million)	41	73	152	310
Wildfire Damage Prevention ($ Million)	6	8	13	20
Erosion Damage Prevention ($ Million)	7	11	17	24
Outdoor Recreation (Million Recreation-Days)	138	268	540	918
Sport Fishing (Million Man-Days)	4	10	15	26
Hunting (Million Man-Days)	1.3	2.1	3.5	5.1
Irrigation (1,000 Acres)	1,315	1,488	1,579	1,613
Drainage (1,000 Acres)	212	280	312	400

Table A-3
Framework Program for Development of Water and Related Land Resources
Lower Colorado Region
(Increments in Each Time Frame)

		Units	1966-1980 Quantity	1966-1980 Cost (Million Dollars)	1981-2000 Quantity	1981-2000 Cost (Million Dollars)	2001-2020 Quantity	2001-2020 Cost (Million Dollars)
A.	WATER RESOURCE PROGRAM (streamflow control and inplace use)							
1.	Reservoir storage for withdrawal and inplace use	million acre-feet	3.71	46	1.32	132	0.28	30
2.	Flood Control			359		337		248
	(a) Reservoir and detention storage	million acre-feet	3.15	(228)	0.60	(98)	0.65	(147)
	(b) Levees and channel improvement	miles	859	(110)	455	(205)	245	(56)
	(c) Nonstructural measures	--	--	(15)	--	(24)	--	(34)
	(d) Land Treatment	thousand acres	188	(6)	280	(10)	265	(11)
3.	Augmentation of Regional Water Supply	million acre-feet per year		787		4,225		3,373
	(a) Imports to the Region	million acre-feet per year	--	--	2.25	(3,600)	1.00	(3,000)
	(b) Water slavage	million acre-feet per year	0.30	(42)	--	--	--	--
	(c) Precipitation management	million acre-feet per year	--	--	--	--	--	--
	(d) Water yield improvement	million acre-feet per year	0.03	(16)	0.09	(33)	0.06	(35)
	(e) Intraregional transfers	million acre-feet per year	1.67	(729)	3.00	(592)	1.08	(338)
4.	Water Quality, Pollution Control, and Health Factors	million gallons per day		126		108		327
	(a) Waste water treatment	million gallons per day	270	(91)	440	(102)	530	(165)
	(b) Quality and pollution control	million gallons per day	268	(35)	320	(6)	510	(2)
	(c) Drainage water treatment	million gallons per day	--	--	--	--	150	(160)
5.	Single-purpose M&I Water Supply Development	million acre-feet per year	0.41	109	0.83	279	1.07	140
6.	Hydroelectric Power (pumped storage)	million kilowatts per year	0.8	76	3.7	377	9.1	624
	TOTALS, WATER RESOURCE PROGRAM COSTS			1,503		5,458		5,042
B.	RELATED PROGRAMS							
1.	Land Treatment and Management	thousand acres	18,425	156	27,026	305	16,745	159
	(a) For water yield improvement (see item A.3.(d)above)	thousand acres	(250)	(--)	(600)	(--)	(450)	(--)
	(b) For erosion, sediment, and runoff control	thousand acres	(18,175)	(156)	(26,426)	(305)	(16,295)	(159)
2.	Irrigation and Drainage	thousand acres		248		277		162
	(a) Land preparation, onfarm facilities	thousand acres	573	(56)	801	(78)	779	(76)
	(b) New distribution systems	thousand acres	347	(108)	596	(184)	132	(41)
	(c) Rehabilitation of existing distribution systems	thousand acres	429	(70)	--	--	--	--
	(d) Drainage developments	thousand acres	68	(14)	32	(15)	88	(45)
3.	Outdoor Recreation (water-based developments)	million recreation days	0	0	86	107	9	38
4.	Fish and Wildlife	thousand man-days	4,022	51	7,014	114	11,794	208
5.	Wild and Scenic Rivers 1/	miles	1,080	--	--	--	--	--
	TOTALS, RELATED PROGRAM COSTS			455		803		567
C.	OTHER ASSOCIATED PROGRAMS							
1.	Land Treatment and Management	thousand acres	7,409	43	9,410	79	6,840	48
2.	Outdoor Recreation (additional development and land acquisition)	million recreation days	51	194	93	338	106	375
3.	Fish and Wildlife	thousand acres	331	1	3,629	1	7,845	1
4.	Preservation of Cultural and Scenic Values 1/ Wilderness Areas	thousand acres	2,762	--	1,700	--	300	--
5.	Other Electric Power	million kilowatts		739		5,000		16,000
	(a) Thermal power	million kilowatts	1.9	(229)	22.8	(2,600)	77.8	(10,000)
	(b) Transmission facilities	--	--	(510)	--	(2,400)	--	(6,000)
	TOTALS, OTHER ASSOCIATED PROGRAM COSTS			977		5,438		16,424

1 Areas requiring further study to define required scope of development.

Table A-4
Remaining Needs Unsatisfied by Framework Program 1/

	Annually at End of Time Frame		
	1980	2000	2020
Water Supply (Million Acre-Feet)	1.48	0.44	0.17
Flood Damage Prevention ($ Million)	41	50	68
Recreation (Million Recreation-Days)	93	101	192
Wildfire Damage Prevention ($ Million)	7.4	9.7	12.0
Erosion Damage Prevention ($ Million)	8.2	7.0	6.3

1/ Not included for lack of practicable solutions and legal and institutional constraints.

LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY

MAIN REPORT

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PHOTOGRAPHS

The photographs utilized in this report were selected from a large collection supplied by participants in the study. The following contributors and others are gratefully acknowledged:

National Park Service
Forest Service
Bureau of Mines
Salt River Project
Soil Conservation Service
Arizona Game and Fish
Bureau of Sport Fisheries and Wildlife
Corps of Engineers
Bureau of Land Management
Bureau of Indian Affairs
Bureau of Reclamation

INTRODUCTION

CHAPTER A - INTRODUCTION

AUTHORIZATION, PURPOSE AND SCOPE

The Lower Colorado Region is one of the major river basins in the United States included in a nationwide program to provide comprehensive river basin plans for the development, use, and management of water and related land resources. This program stemmed from recommendations of the Senate Select Committee on National Water Resources, and planning concepts are embodied in Senate Document No. 97, 87th Congress, Second Session. The overall program was presented by the President in the Fiscal Year 1963 budget. The Lower Colorado Region study was approved by Congress, and funds were provided to start this activity in Fiscal Year 1967.

The States of Arizona, California, Nevada, New Mexico, and Utah participated with the various Federal agencies in this investigation.

The basic objective in the formulation of framework plans is to provide a broad guide to the best use, or combination of uses, of water and related land resources in each region to meet foreseeable short- and long-term needs. In studies to achieve this basic objective, consideration was given to: (a) the timely development and management of these resources as essential aids to the economic development and growth of a region; (b) the preservation of resources, in appropriate instances, to insure that they will be available for their best use as needed; and (c) the well-being of all of the people as the overriding determinant in such planning.

The studies made for this report are preliminary, or reconnaissance, in scope. All geographic areas within the region and all purposes served by the conservation, development, and use of water and related land resources were considered. Available data pertinent to the study that have been collected, developed, and cataloged over the years by local, State, and Federal agencies were utilized. The studies considered only intraregional water and related land resources use except for those interregional water uses established by prior compacts and agreements.

This study deals with the water and related land resources of the Lower Colorado Region involving all significant problems and beneficial uses associated with these resources. Consideration is given to various aspects of problems related to supplies of water for municipal and industrial purposes, water quality control, Mexican Treaty obligation, allocations under the "Law of the River," flood control, irrigation, electric power production, mining and mineral processing, land resources and uses,

watershed management, outdoor recreation, fish and wildlife habitat, the environment and the well-being of the people of the Region. Environmental aspects such as natural beauty, cultural and historic values, rare species of flora and fauna, wildlife in general, and quality goals are considered to be integral parts of the fabric of an optimum framework program.

Investigations in the Lower Colorado Region cover most of the State of Arizona and parts of Utah, Nevada, and New Mexico.

The study period was established to run from 1965 (base year) to the year 2020. In order to identify and stage early, intermediate, and late action programs, the study period was divided into three time frames: 1966 to 1980, 1981 to 2000, and 2001 to 2020.

STUDY GUIDELINES

General guidelines for framework studies were prepared by the Water Resources Council and Pacific Southwest Inter-Agency Committee. The following guidelines were formulated in the early stages of the study and were prevailing considerations during the course of the study:

(a) Projections of regional growth and development are generally constrained in accordance with the national projections developed by the Departments of Agriculture and Commerce (OBE-ERS) and supplied to the Region by the Water Resources Council.

(b) For the duration of the study period, there will be no catastrophic wars, no national political upheaval, no major economic depressions, nor any other changes that would upset the projected socio-economic trends.

(c) Water presently being beneficially used will not be diverted to supplement growing urban or industrial demands, except where urban or industrial growth occupies land on which water is beneficially used for another purpose.

(d) Considerations for transbasin diversions of fresh water supplies from sources outside the Pacific Southwest area are precluded.

(e) Intrabasin transfers of water can be considered for redistribution of available water supplies.

(f) The distribution of water between regions will be made in accordance with existing compacts and legal agreements.

(g) Maintenance of environmental quality will be given high priority in planning for the future.

(h) Only general consideration will be given to cost-repayment capacity relationships for selection of a plan of water and land development. The plan will be based essentially upon the reasoned judgment of competent planners.

(i) Importation of desalted sea water to the Region can be considered a potential source of supply.

(j) In the Lower Colorado Region, Section 605 of Public Law 90-537 (Colorado River Basin Project Act) states that "Part I of the Federal Power Act (41 Stat. 1063; 16 USC 791a-823) shall not be applicable to the reaches of the main stream of the Colorado River between Hoover Dam and Glen Canyon Dam until and unless otherwise provided by Congress." Public Law 90-537 also prohibits construction of hydroelectric plants as part of the Colorado River Basin Project.

COOPERATING AGENCIES

To adequately cover all technical aspects of this comprehensive study and to enlist the viewpoints of Federal, state, and local interests, many agencies, institutions, and organizations contributed to the studies. Federal, state, and local agencies and organizations exchanged information and coordinated their work directly among themselves. Periodic joint meetings of the cooperating agencies were conducted at field level to review findings and to exchange data and views.

METHOD OF APPROACH

For the purpose of this study, the Lower Colorado Region was divided into three hydrologically delineated subregions and to accommodate the socio-economic statistical analyses, the Region and subregions were extended to the closest fitting political boundaries. The latter delineations were designated the "economic region" and the "economic subregions" and all population and economic data are presented on that basis, unless otherwise noted. All projections of water related socio-economic factors were adjusted to represent the designated hydrologic areas. Investigations were first conducted by subregions. These subregional studies were then coordinated, interrelated, and combined to determine the overall program for the Lower Colorado Region.

The study program consisted of three basic elements:

(a) Evaluation of present and projected needs for goods and services which place a demand on water and related land resources;

(b) Evaluation of resources and facilities, including those in authorized and potential projects, which will be available to serve the demands; and

(c) Formulation of a general Lower Colorado Region framework development program to serve immediate and future needs.

COORDINATION AND ADMINISTRATION

To fully utilize the capabilities of Federal and state agencies with expertise in all fields of planning, separate work groups were established to prepare each of the functional appendixes required to support this report. Generally, the chairmanship of each work group was vested in the agency having the most appropriate background related to the function. The 16 appendixes developed are listed on the inside front cover of this report.

The Lower Colorado Region Staff, under the chairmanship of the Department of the Interior, reviewed the progress of the work groups, resolved coordination problems, ascertained that established policies and study guidelines were followed, and made recommendations on study procedures and policies.

The Lower Colorado Region State-Federal Interagency Group (LCRSFIG), with members representing the interests of the states and Federal agencies, was responsible for the overall coordination of the study. The group also performed an inline function between the Lower Colorado Region Staff and the Pacific Southwest Inter-Agency Committee--Coordinated Planning Subcommittee.

This, the Main Report, summarizes and integrates the findings of the work groups and presents the framework proposals for development of the Lower Colorado Region. The data, facts, projections, and topic matter discussed herein are substantiated in Appendix XVIII, General Program and Alternatives, and in greater detail in the various functional appendixes.

DESCRIPTION OF THE REGION

CHAPTER B - DESCRIPTION OF THE REGION

GENERAL

The Lower Colorado Region, with a total area of 141,137 square miles, embraces 106,982 square miles of Arizona, 13,355 square miles of New Mexico, 17,310 square miles of Nevada, and 3,490 square miles of Utah. Excluding a portion in southern California, the Region is hydrologically defined by the drainage area of the Colorado River in the United States below Lee Ferry, near Glen Canyon Dam. In addition, it includes several closed basins in Arizona, New Mexico, and Nevada, and some areas in Arizona and New Mexico that drain into Mexico. Areawise, the Region represents about 4.8 percent of the contiguous United States and about 7.1 percent of the area west of the Mississippi River.

Three major drainage areas divide the Region into subregions: Subregion 1, Lower Main Stem, 56,554 square miles; Subregion 2, Little Colorado, 26,977 square miles; and Subregion 3, Gila, 57,606 square miles.

The Region was among the earliest to be explored by Europeans, yet, until around 1900, settlement was slow and did not really gather momentum until the modern technologies for pumping ground water and regulating streamflows were perfected and put to use.

Dominant influences on the socio-economic growth of the Region have been the availability of land suitable for many uses, the rich mineral resource, and the very attractive mixture of scenery and climate; the primary limiting influence has been the inadequate and poorly distributed water supply.

Early enterprise was principally centered around mining such metals as copper, gold, and silver. Then, with improved water production and management, irrigated agriculture came into equal prominence. More recently, light industries have grown into major economic importance and presently contribute nearly twice the combined dollar value of the mining and agriculture sectors.

Parts of the Region have become meccas for retirement, recreation, and entertainment which have boosted the regional noncommodity dollar output to more than the combined amount from all other regional economic sectors.

LAND FORMS AND GEOLOGY

The Lower Colorado Region is composed of a complex of plateaus, mountains, canyons, deserts, and plains, with elevations ranging from 75 feet above sea level near Yuma, Arizona, to over 12,600 feet above sea level at Humphreys Peak near Flagstaff, Arizona. The topography takes in virtually every form and degree from level plains to precipitous mountains and canyons between these elevation extremes.

Similarly, the geology of the Region includes a broad spectrum of sedimentary, metamorphic and igneous rocks which produce a wide variety of soils locally and along stream courses. In short, the principal physical characteristics of the Region are its great variety of land forms, topography, and geology.

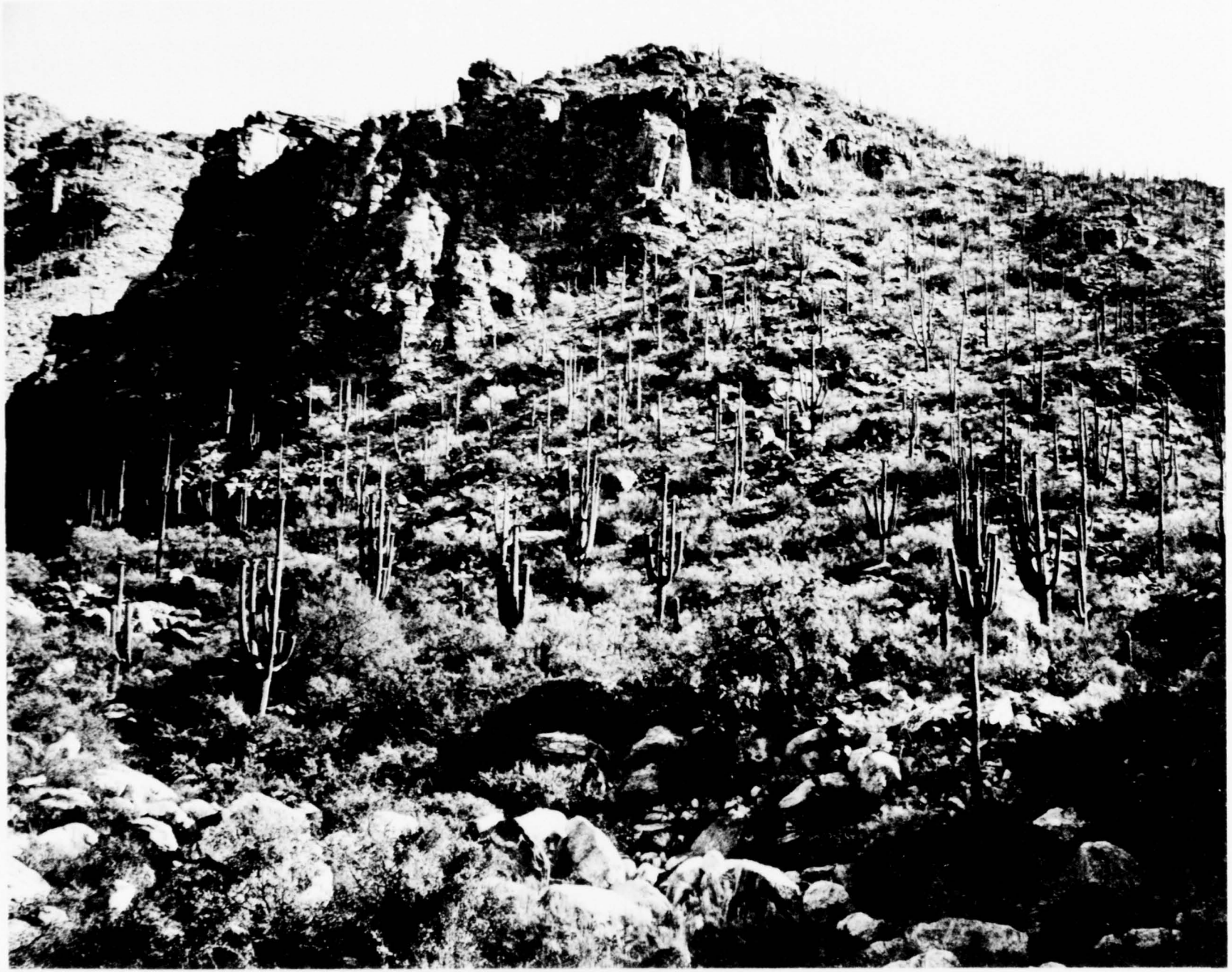
STREAM DEVELOPMENT

Many of the streams tributary to the Colorado River head in narrow canyons and run through deeply cut gorges. The Colorado River became a through-flowing stream in the late Cenozoic time. Downcutting by the river and its tributaries resulted in deep entrenchment of the entire system creating spectacular canyons, most notable of which is the Grand Canyon of the Colorado. All runoff from the high plateaus and mountains in the Lower Colorado Region is tributary to the Colorado, Little Colorado, and Virgin Rivers. The Colorado and Virgin Rivers are perennial; all other streams are intermittent at their confluence with the Colorado River except for short reaches downstream from springs such as Blue Spring and those in Havasu Canyon and near St. Johns, Arizona.

As measured in terms of fish habitat, there are approximately 2,500 miles of perennial streams in the Region, but much of the tributary runoff never reaches the Colorado River.

GROUND-WATER BASINS

The storage and movement of ground water in sedimentary rocks are controlled by regional structure of the basins and upwarps. Storage and movement in alluvial basins are frequently controlled by valley plugs created by lava flows, tectonic movement, and nearly impervious alluvial deposits. The main areas of recharge are on the highlands, on the upwarps, and along the structural divides. Movement of ground water is downdip from the highlands toward the perennial streams.



IMPOUNDMENTS

The Colorado River is almost completely controlled by the Upper Colorado River Basin Storage Projects and Lake Mead, having combined storage capacity of about 60 million acre-feet. Within the Lower Colorado Region, aggregate usable capacity of 15 significant impoundments on the Colorado River and tributaries is 28.6 million acre-feet and 3.2 million acre-feet, respectively.

CLIMATE

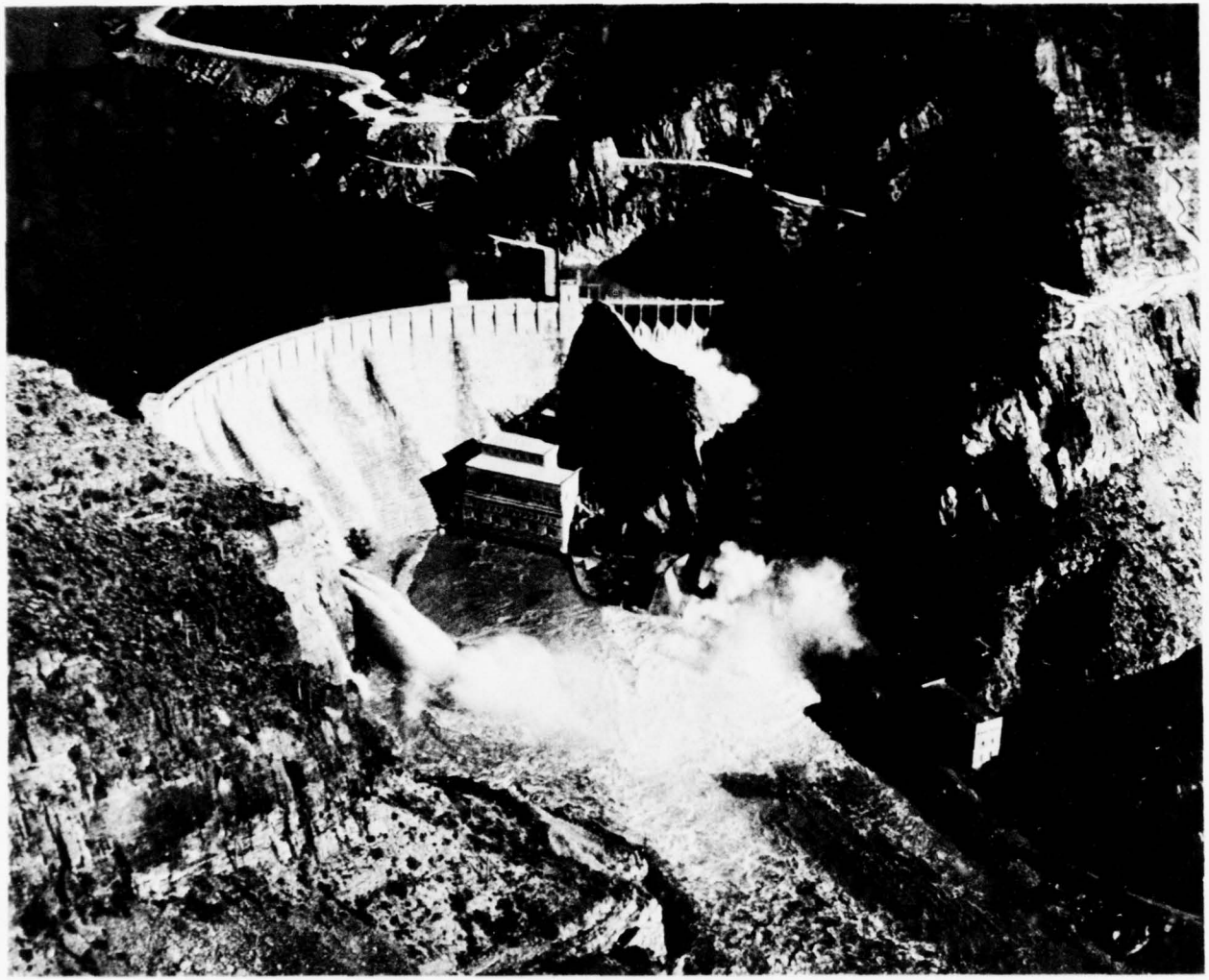
The Lower Colorado Region's climate varies widely because of a large difference in elevation, a considerable range in latitude, and the distribution of mountain ranges and highlands. See Figure 1 for climatic data.

Generally, the climate of the more densely populated areas of the Region, such as Las Vegas, Nevada, and Phoenix, Tucson, and Yuma, Arizona, is characterized by mild to warm annual temperatures, low to moderate humidity, and low annual precipitation. Summer temperatures often reach 100 degrees and above. Rainfall is predominantly in the form of thundershowers which are sometimes very intense and produce flash flooding locally. Except in the mountains, snow is rare and short-lived. Annual frost-free days in the lower desert range from over 270 days to yearlong. Yuma, Arizona, has experienced several years in succession without a killing frost. These climatic factors are very favorable to the irrigated agriculture concentrated in the lower elevations.

In contrast, such cities as St. George, Utah; Winslow and Holbrook, Arizona; and Gallup, New Mexico, have more of a four-season climate with shorter frost-free periods and colder winter months. Flagstaff, Arizona, and other cities in mountainous, rimrock, and plateau locations have substantially shorter frost-free periods, mild summers, cold winters, and considerably more rain and snow. Most of the recharge to ground water and the surface runoff in the Region results from precipitation in the high mountainous areas. Up to 30 inches of precipitation a year are recorded, much of which is in the form of snow.

SOCIO-ECONOMIC ENVIRONMENT

In 1965, the Lower Colorado Region had a population of nearly 1.9 million people and was increasing at the rate of about 4 to 5 percent per year. Nevada and Arizona were No. 1 and No. 3 in national standing for rates of increase.



Theodore Roosevelt Dam, completed in 1911 on the Salt River in Arizona, is the forerunner of multipurpose water storage projects in the Region and still provides flood control, water for irrigation, municipal and industrial uses, hydroelectric power generation, and recreation.

Hoover Dam and Lake Mead exemplify the concept of multipurpose use of stored water including: flood control; power generation; irrigation; recreation; fish and wildlife and other uses.

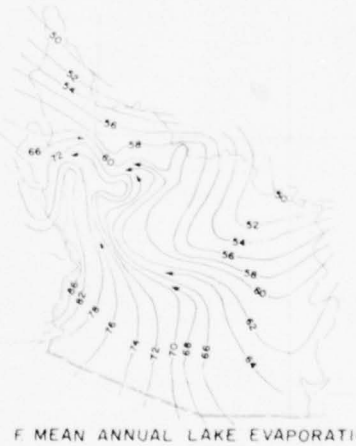
A. NORMAL ANNUAL PRECIPITATION (INCHES)

B. NORMAL MAY-SEPT. PRECIPITATION (INCHES)

C. DAILY AVERAGE TEMPERATURE, JANUARY (°F)

D. DAILY AVERAGE TEMPERATURE, JULY (°F)

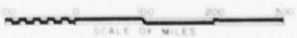
E. MEAN LENGTH OF FROST-FREE PERIOD (DAYS) BETWEEN LAST 32° F TEMPERATURE IN SPRING AND FIRST 32° F TEMPERATURE IN AUTUMN



F. MEAN ANNUAL LAKE EVAPORATION (INCHES)

FIGURE 1

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
CLIMATIC DATA
1019-314-7



SCALE OF MILES

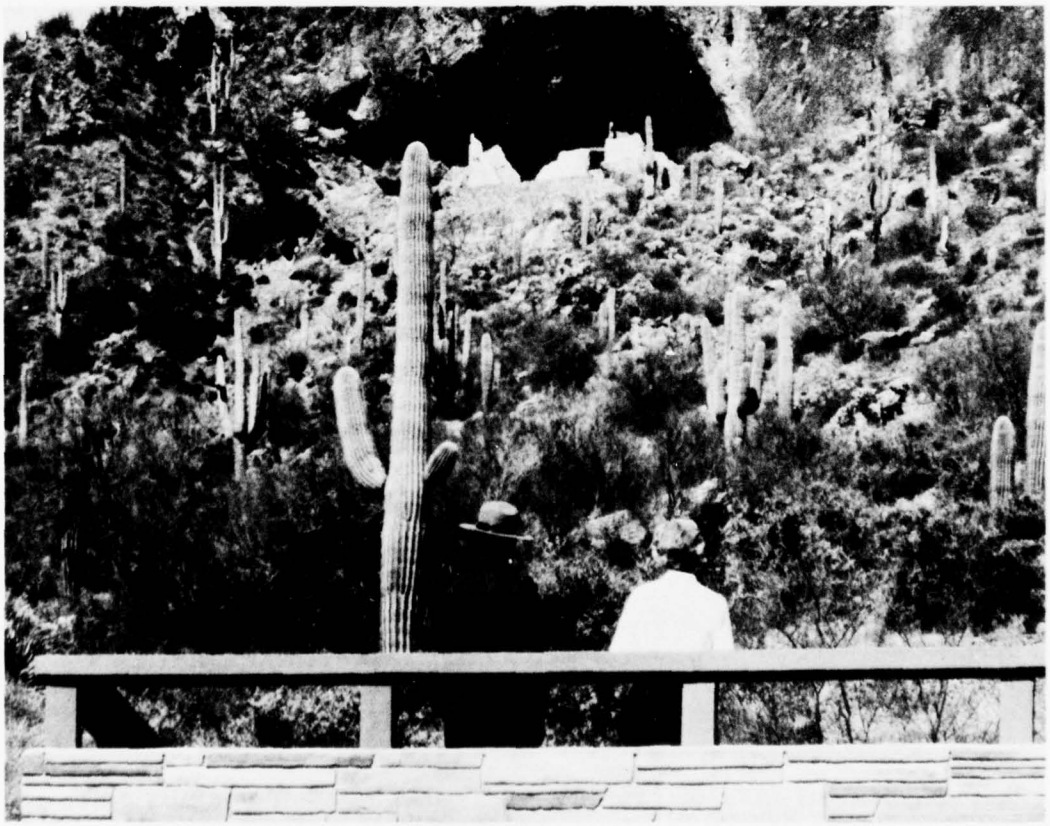
SEPTEMBER 1968

Las Vegas, Nevada, caters to the tourist who likes a game of chance, spectacular shows, and near year-long sunshine.

Phoenix, capitol city of Arizona, ranks as one of the Nation's fastest growing cities; is the heart of the State's industrial empire and a major tourist attraction.

New employment opportunities for the expanding population were principally in the manufacturing, trades, and services-type industries. Agricultural and mining employment in 1965 was in a stable to slightly declining trend. Personal income per capita for the Region was near the national average. About two-thirds of the regional population reside in the metropolitan areas of Phoenix and Tucson, Arizona, and Las Vegas, Nevada. Urban population accounted for 80 percent of the total in 1965.

In 1965, the Region was experiencing a vigorous, healthy upswinging trend of development in the manufacturing, wholesaling, construction, and the trades and services industries. Only the Little Colorado Subregion, which is still primarily a rural area, lagged behind this trend. The combination of climate, employment opportunities, the great variety of striking scenery, and recreation opportunities have attracted residents from all parts of the United States. Immigration accounted for nearly two-thirds of the population growth of the Region during the 1960's.



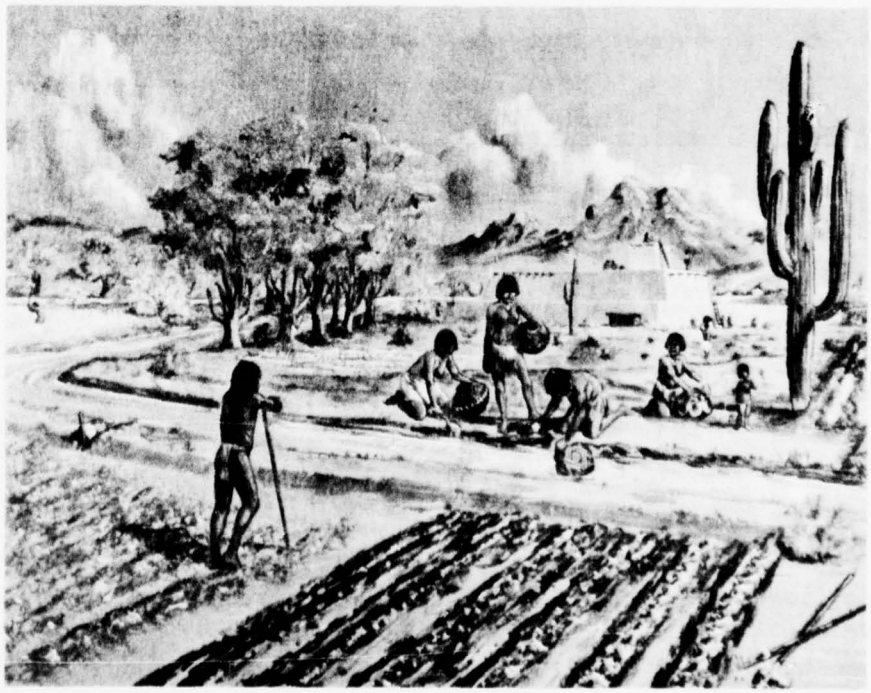
REGIONAL ECONOMY

CHAPTER C - REGIONAL ECONOMY

PATTERN OF ECONOMIC DEVELOPMENT

The population and economic data presented in this chapter are on the basis of the economic region as defined previously. Projections of regional growth and development are based on "OBE-ERS Projections," developed by the Department of Commerce (Office of Business Economics) and the Department of Agriculture (Economic Research Service), and modified by the States of the Region to reflect local conditions and trends, "Modified OBE-ERS Projections."

Historically, economic activity in the Lower Colorado Region has been largely oriented around production of agricultural commodities with mining of minerals and metals intermittently influencing peaks or depressions in the activity curve. Historians and archeologists estimate that prior to the birth of Christ, the Gila and Salt River Valleys in central Arizona had a thriving Indian population oriented around agriculture that may have irrigated in excess of 100,000 acres. Exactly how many people were here is conjectural, but certainly several tens of thousands must have lived and



worked in this economy. However, by the time Spanish explorers entered the Region in the middle 16th Century, this prior civilization was gone and only small settlements of Indians remained, but the economic base was still agriculture.

Steady progressive growth of the Region's economic activity did not start until the middle of the 19th Century when the pioneers crossed the continent by land to capitalize on the gold rush in California. Even with this occurrence, settlement was along the travel routes and active growth was slow. Near the end of the 19th Century, the discovery of gold, silver, and other metals in the Region created a boom in the mining industry and it became the dominant support for the regional economy.

During World War II, a more diversified and expanding economy began to evolve. Hoover Dam's power plant provided a source of plentiful electricity for industry. The yearlong climate was favorable to military training activities and the advent of air conditioning tempered the harshness of the hot summer months. Las Vegas, Nevada, with its flamboyant entertainment industry; Lake Mead, Lake Havasu, and Lake Mohave on the Colorado River; and the lakes formed behind the dams on the Salt, Verde, and Gila Rivers in central Arizona invited recreationists, hunters, and fishermen. The affluent economy that developed during the war started a tourist influx to the arid Southwest to escape the cold winter months occurring elsewhere. Light industry followed to capture a labor pool and to utilize the yearlong working environment.

By 1965, the total gross output from manufacturing was nearly twice that of mining and agriculture combined, and the noncommodity producing activities were almost four times as great as these two historic activities.

Population and Its Distribution

From a population standpoint, the Region is a part of the fastest growing area in the United States. In the 15-year period from 1950 to 1965, the population more than doubled. About two-thirds of the 1965 population resided in the three metropolitan areas of Las Vegas, Nevada; Phoenix and Tucson, Arizona.

In 1960, population distribution was classified as about 74 percent urban and 26 percent rural. In the Little Colorado Subregion, which contains no large cities, the ratio of urban to rural is almost exactly reverse that of the Region, being 72 percent rural and 28 percent urban.

Employment and Income

Of the total 1965 population of 1,877,000 people, some 675,000 were classified as employed. See Figure 2. The total personal income for the Lower Colorado Region in 1965 was approximately $4.3 billion, or an average

of about $6,400 per employed worker, related in 1960 dollars, while the per capita income was about $2,300. This is slightly lower than the national average per capita income. Gross Regional Product--the payments to local, state, and Federal governments, wage payments, and profit and other income, including depreciations--amounted to over $6 billion in 1965.

Industries

In 1965, there were about 7,900 farms in the Region excluding Indian reservations. The value added to the regional economy by agricultural production in 1965 was $232 million; about 5 percent of total value added. Indirectly, agriculture provides a much greater contribution to the economy since large quantities of industrial goods are used in producing, processing, and marketing agricultural products. Agriculture also provided jobs for about 6 percent of the people employed. For all practical purposes, the crop production is on irrigated land located largely in the lower desert areas. The Region produces a significant amount of the Nation's citrus, and during the winter and early spring months, much of the Nation's vegetables are produced here. See Figure 3 for percentages of value added by industries.

In 1965, value added from the mining industry totaled some $317 million and the industry employed about 18,000 people. The Lower Colorado Region produces almost 60 percent of the copper produced in the United States and nearly 41 percent of the uranium ore. Likewise, it produces nearly 10 percent of the gold, 14 percent of the molybdenum, 16 percent of the silver, 10 percent of the zinc, and 23 percent of the pumice.

Forestry, in 1965, employed less than 10,000 people and the value added from forest products was about $12 million. The forests and timberlands support much of the wildlife, are enjoyed by many thousands of recreationists, and support about 30 percent of the total livestock grazing. The forest land occupies nearly a third of the total land area in the Region.

Other commodity producing industries consist of manufacturing and the processing of natural resource commodities produced or imported into the Region. In 1965, value added from these economic activities was $741 million and employment was about 90,000 people. Industries represented in this category include food and kindred products; lumber and wood products; chemicals; printing and publishing; fabricated metals; primary metals; stone, clay, and glass products; textiles and apparels; leather and leather goods; and other minor manufacturing plants.

Numerous assembly plants for small electronic-associated products and such products as radios, refrigerators, and television sets, are located in central Arizona. Fabrication and development of many items used in the NASA program are located in the Region. The large chemical

FIGURE 2
EMPLOYMENT BY INDUSTRIES - 1965

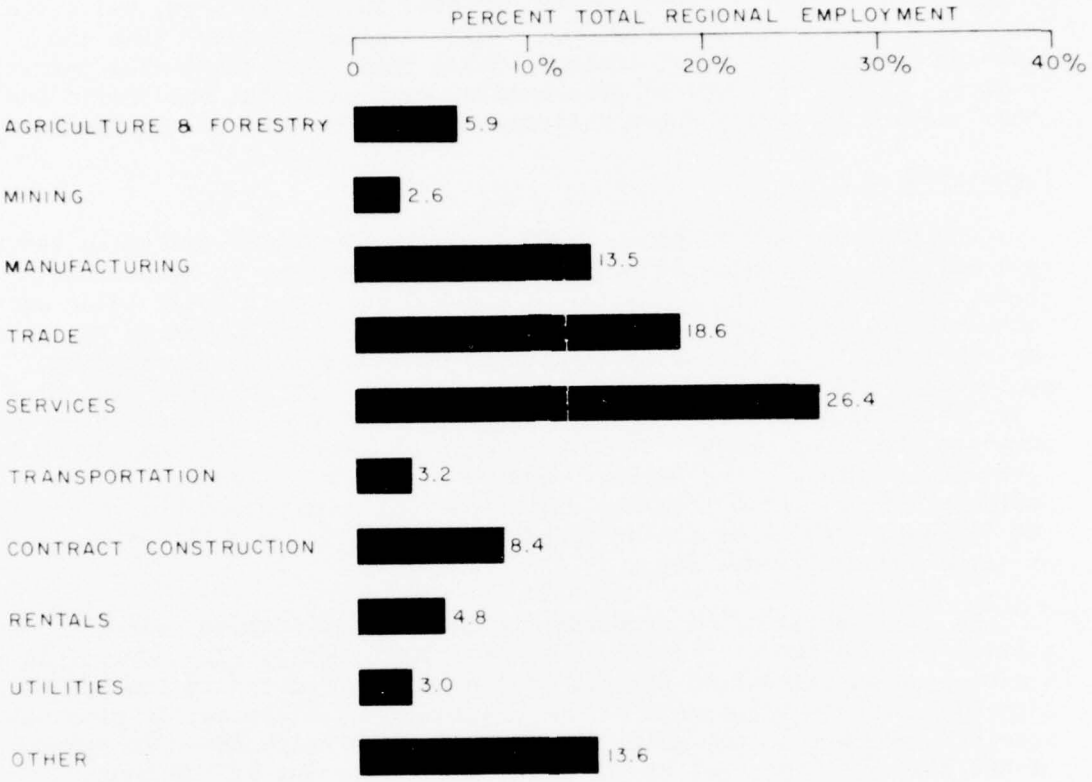
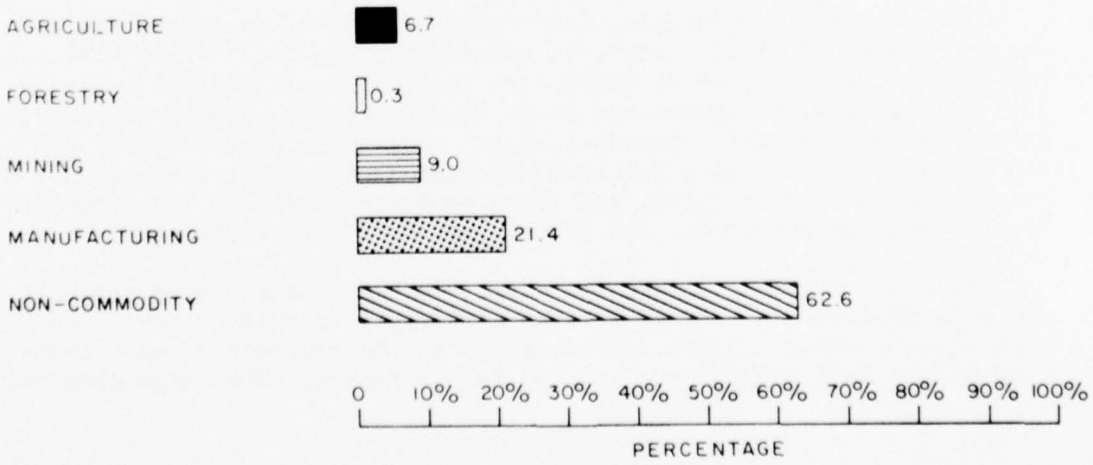


FIGURE 3
PERCENTAGE OF GROSS OUTPUT BY INDUSTRY - 1965
(BASED ON VALUE ADDED)



manufacturing plants located at Henderson, Nevada, also employ a large number of workers.

The noncommodity producing industries consist mainly of wholesale and retail trade, the electric utilities, contract construction, food and lodging, transportation, rentals, finance, and similar service-type activities. Value added by these industries in 1965 amounted to about $2.2 billion; employment was approximately 435,000. See Figure 3 for percentages of gross output by industries.

Economic and Population Projections

The role of irrigated agriculture in the Region's economy is expected to continue and to grow in the future; however, the contribution will decrease in importance to the total economy. It is expected that the irrigated harvested acreage will increase from 1,226,000 acres in 1965 to 1,584,000 acres in 2020; employment, 39,000 to 43,000; and total value added, $232 million to $647 million.

Forestry and forest products are expected to follow a trend similar to irrigated agriculture. Employment will decrease from about 9,000 in 1965 to about 8,000 in 2020, while total value added is expected to increase from $12 million in 1965 to $18.3 million in 2020.

In the mining industry, employment is projected to remain at about 16,000 to 18,000 people throughout the study period. Total value added from mining, however, is expected to increase from $217 million to about $895 million.

Manufacturing activities show rather spectacular growth between 1965 and 2020. Manufacturing employment is projected to increase from about 90,000 people in 1965 to over 478,000 in 2020. Total value added from this activity is projected to increase from about $741 million in 1965 to more than $13 billion during the projection period.

The noncommodity producing industries are projected to become much more dominant in the future. These activities employed about 435,000 people in 1965 and value added was about $2.2 billion. By 2020, it is projected that some 2,036,000 people will be employed in these industries and total value added will be about $36 billion.

The per capita income and the earnings per employed worker reflect similar characteristics of growth during the study period. Per capita income, about $2,300 in 1965, is projected to increase to about $12,000 in 2020, and the per employed worker income of $6,400 in 1965 is projected to be $23,500 by 2020.

Population growth during the period 1965 to 2020 is expected to continue at a steep upward trend though at a somewhat lower rate than has occurred since 1940. By 2020, regional population is expected to reach nearly 6,983,000 people; an overall increase of 5.1 million between 1965 and 2020.

The following tabulation shows the population distribution for years 1965, 1980, 2000, and 2020 by economic subregions and region:

Estimated and Projected Population
Lower Colorado Region

Area	Estimated 1965	Projections 1980	2000	2020
		-------Thousands--------		
Region	1,877	2,911	4,797	6,983
Lower Main Stem Subregion	345	816	1,520	2,021
Little Colorado Subregion	125	184	240	326
Gila Subregion	1,407	1,911	3,037	4,636

PRESENT STATUS OF DEVELOPMENT

CHAPTER D - PRESENT STATUS OF RESOURCE USE AND DEVELOPMENT

WATER RESOURCES

The Lower Colorado Region probably comes closer to using the last drop of available water for man's needs than any other area in the United States. These water supplies are also among the most regulated and metered in the Nation. Despite the most frugal use, recycling, and the highly efficient regulation of water, the Region is mining water each year that cannot be replenished by natural recharge for many decades. Virtually every sector of the Region's socio-economic structure is being sustained in some degree by the overdraft of ground water.

Three main sources of water were available in 1965 for use in the Lower Colorado Region:

(a) Entitlement to 3.1 million acre-feet of Colorado River water by a body of law referred to as the "Law of the River;"

(b) Local runoff amounting to 3.12 million acre-feet originating within the regional boundaries; and

(c) Local ground-water reserves.

The 3.1 million acre-feet entitlement from the Colorado River has not been fully utilized because of the lack of conveyance facilities to transport water to the areas of heavy demand. About 8.2 million acre-feet were withdrawn from surface- and ground-water sources in 1965. Approximately 5 million acre-feet, about 60 percent, of this was from ground-water reserves of which an estimated 2.5 million acre-feet were in excess of the annual replenishment.

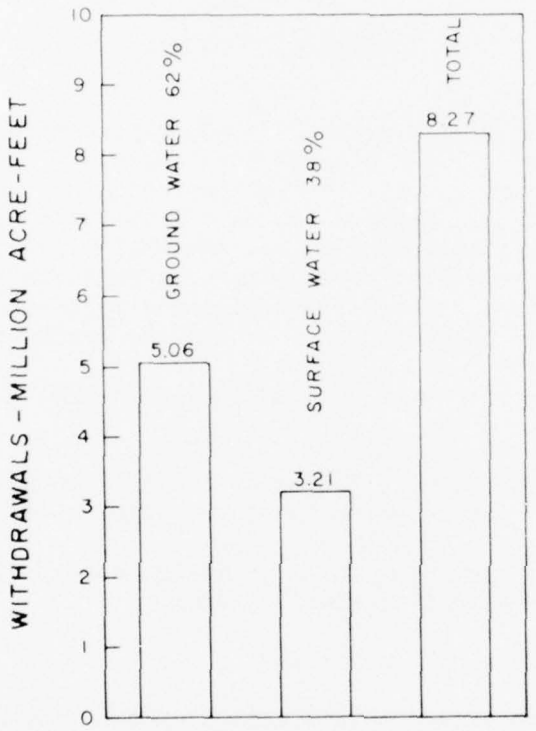
The area of greatest use of water for municipal, industrial and irrigation purposes was the Phoenix-Tucson area of Arizona where most of the Region's ground-water overdraft occurred. Las Vegas Valley, Nevada, lacking facilities for diversion of adequate quantities of Colorado River water, was also pumping from ground-water reserves in 1965.

Figure 4 compares the amounts and proportionate parts of water withdrawn in 1965 from ground water and surface water.

About 94 percent of the total regional water withdawal was for irrigation, and 6 percent was for municipal, industrial, and all other uses. Only minor quantities are used for electric energy generation, mineral production, fish and wildlife, and recreation.

FIGURE 4

SOURCES OF WATER - 1965



WATER QUALITY

Regionally, water quality as expressed by total dissolved solids (TDS) concentrations is generally of lower quality than in many other parts of the Nation. The Colorado River enters the Region at concentrations exceeding 500 mg/l and varies between 600 and 900 mg/l at major diversion points within the Region. Salinity increases in the Colorado River are due principally to inputs from saline springs and the concentrating effects of consumptive use and surface evaporation from reservoir and river water surfaces.

In the headwaters of the Gila, TDS concentrations are generally less than 500 mg/l; and, in the middle reaches, the dissolved salt content usually ranges from about 500 to 1,000 mg/l.

Water quality is generally good in most of the headwaters of the Little Colorado River but at its confluence with the Colorado River, it contains very high concentrations of dissolved solids from saline springs located near its mouth. The Colorado River has a hardness (as calcium carbonate) varying from about 330 mg/l at Lee Ferry, Arizona, to about 370 mg/l at Imperial Dam. Downstream at Yuma, Arizona, the hardness increases to 700 mg/l. Although fluoride content ranges from a trace to about 4 or 5 mg/l, it is normally about 1 mg/l or less in most water of the Region. Sediment concentrations in surface water of the Region range from very high to moderate. The areas of greatest sediment yield are located in northwestern Arizona and southwestern Utah where sediment concentrations as great as 700,000 parts per million have been measured and 500,000 ppm observations are not unusual.

Nutrients from manmade sources have caused excessive algal growths in Las Vegas Bay of Lake Mead, and in isolated cases, bacterial concentrations have exceeded desirable levels in streams below smaller communities. Occasional overflows and breaks in mining waste disposal systems have resulted in fish kills.

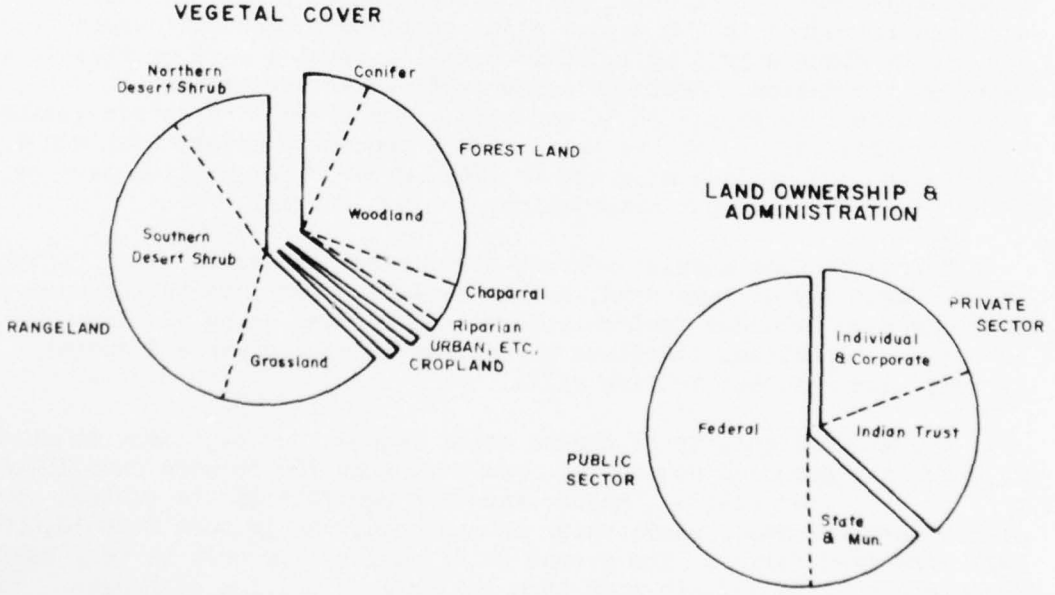
The mineral quality of ground water ranges from excellent to unsuitable for any purpose, containing from less than 100 to more than 100,000 mg/l of dissolved solids. Major sandstone aquifers in the Plateau Uplands of northern Arizona contain water having consistently more than 10,000 mg/l dissolved solids. The ground water ranges from soft to very hard, from less than 60 mg/l to more than 180 mg/l of calcium carbonate. The concentrations of the minor constituents such as iron, magnesium, and silica vary considerably throughout the Region; but, except for fluoride and nitrate, the concentrations are not objectionable for most uses. Boron concentrations of 0.4 mg/l have been observed in the Colorado River at Imperial Dam.

LAND RESOURCES AND USE

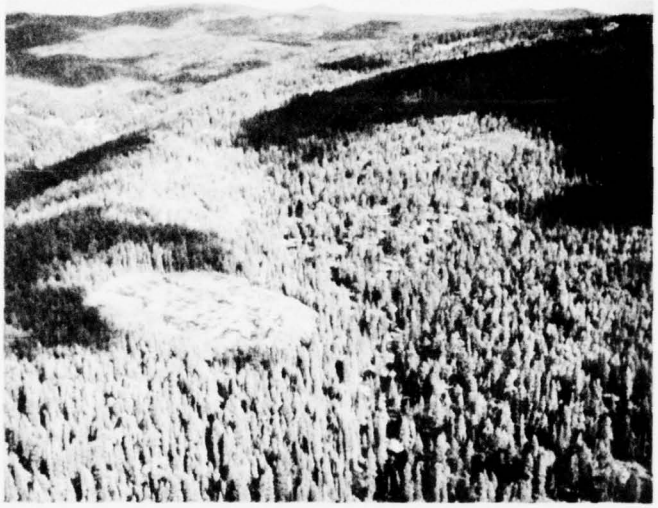
Land ownership within the Region in 1965 was unique in that 64 percent was in public ownership and only 36 percent was private. About half the private land is in Indian trust.

The Region has a wide variation in vegetal cover types and related categories that determine the resources, uses, and developments that exist or may be projected. The natural vegetation ranges from desert through the chaparral and mountain brush, pinyon juniper and oak woodland, to the yellow pine and spruce-fir forest, to alpine and tundra-type on top of the highest mountains. The vegetal cover is dependent upon the climate, elevation, soil, geologic formation, and topography.

In 1965, about 2 percent of the Region was in cropland; 64 percent, pasture and range; 33 percent, forest and woodland; and less than 1 percent in urban, transportation, utilities, etc.



See maps "Land Ownership and Administration" and "Vegetal Cover" presented on the following pages.

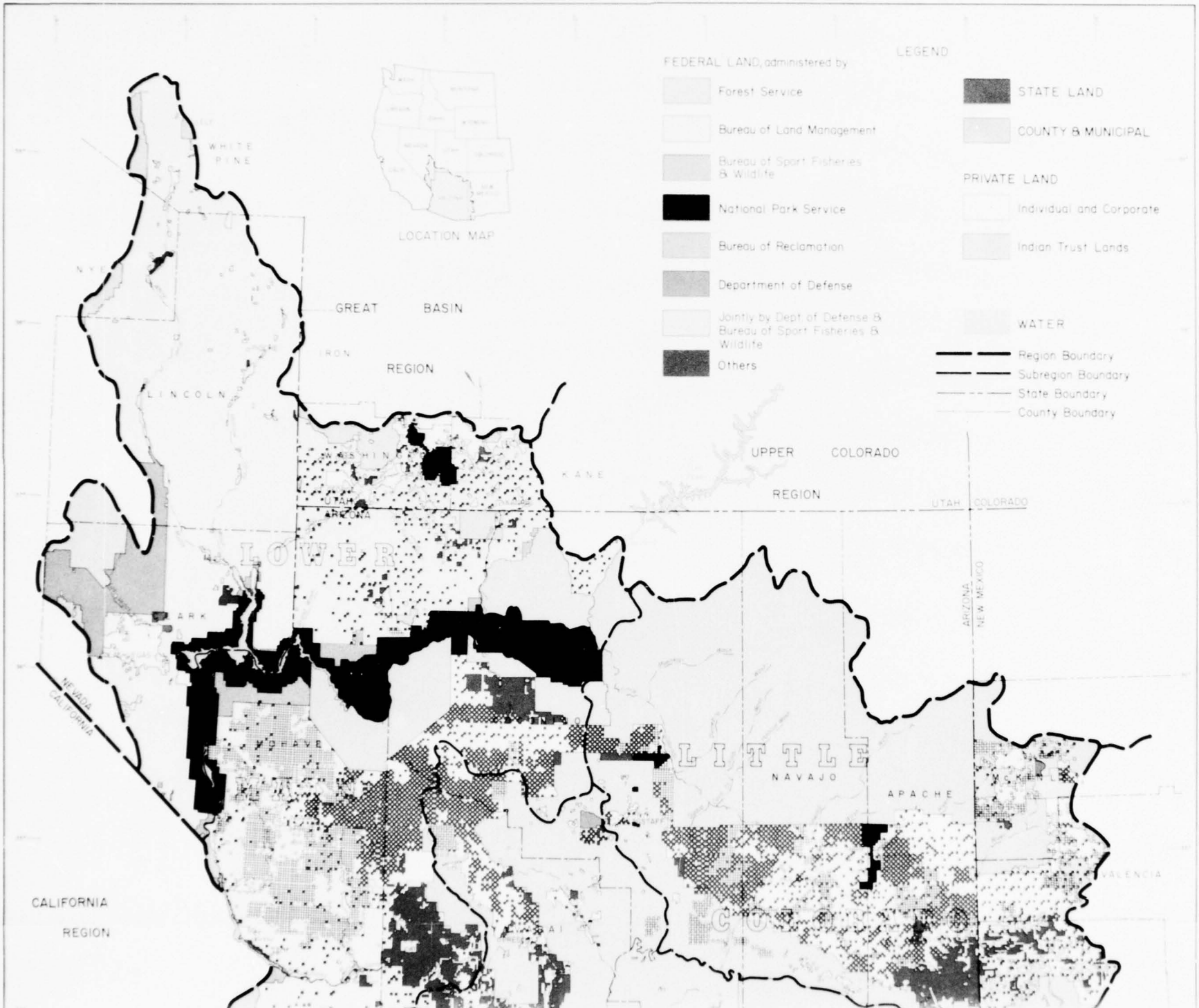


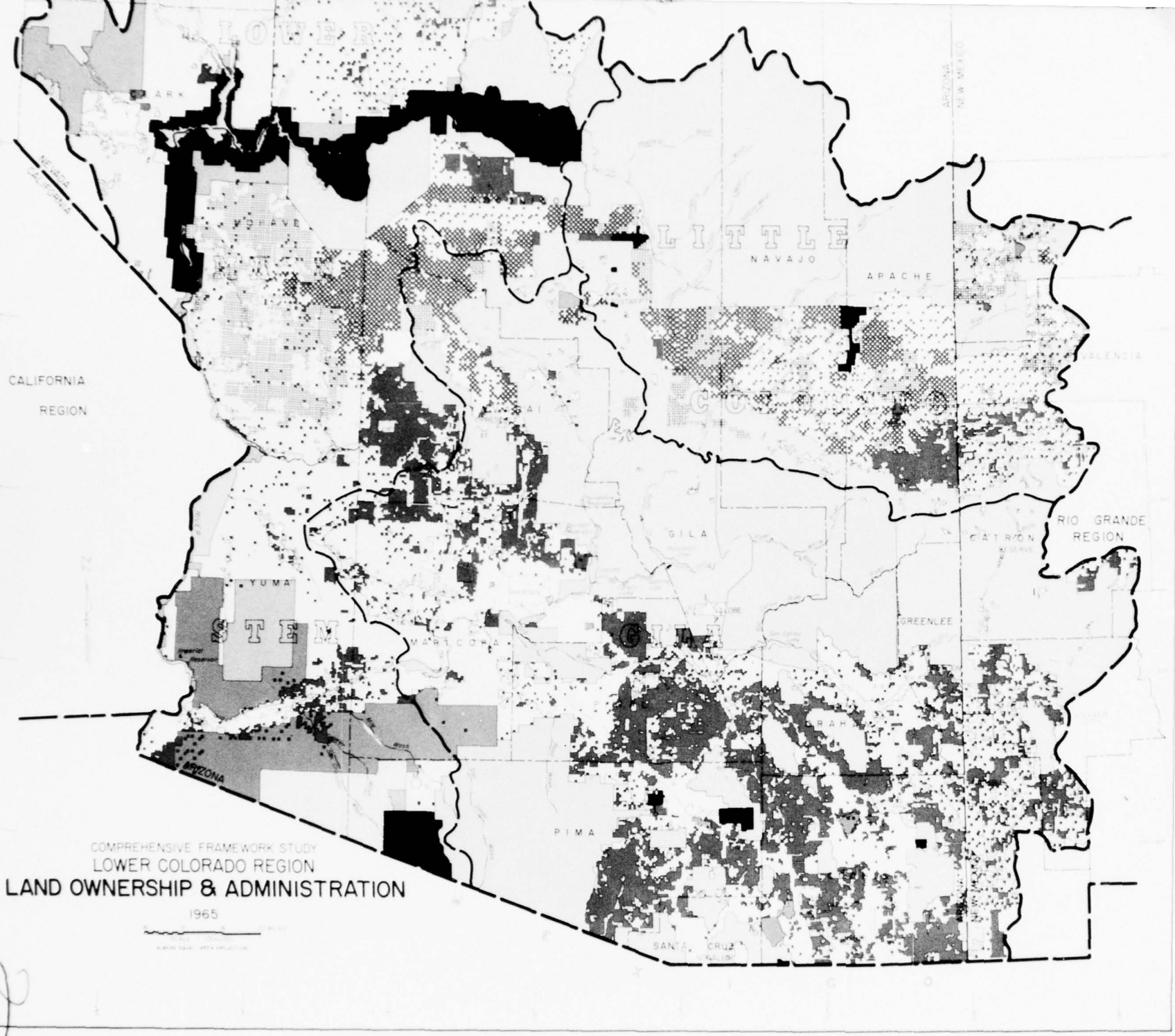
Coniferous Forest

Southern Desert Shrub

Woodland

Riparian


LEGEND
FEDERAL LAND, administered by
Forest Service
Bureau of Land Management
Bureau of Sport Fisheries & Wildlife
National Park Service
Bureau of Reclamation
Department of Defense
Jointly by Dept. of Defense & Bureau of Sport Fisheries & Wildlife
Others
STATE LAND
COUNTY & MUNICIPAL
PRIVATE LAND
Individual and Corporate
Indian Trust Lands
WATER
Region Boundary
Subregion Boundary
State Boundary
County Boundary
LOCATION MAP
GREAT BASIN REGION
UPPER COLORADO REGION
LOWER
LITTLE
CALIFORNIA REGION
WHITE PINE
LINCOLN
IRON
KANE
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
CALIFORNIA
MOHAVE
NAVAJO
APACHE
COCONINO
VALENCIA



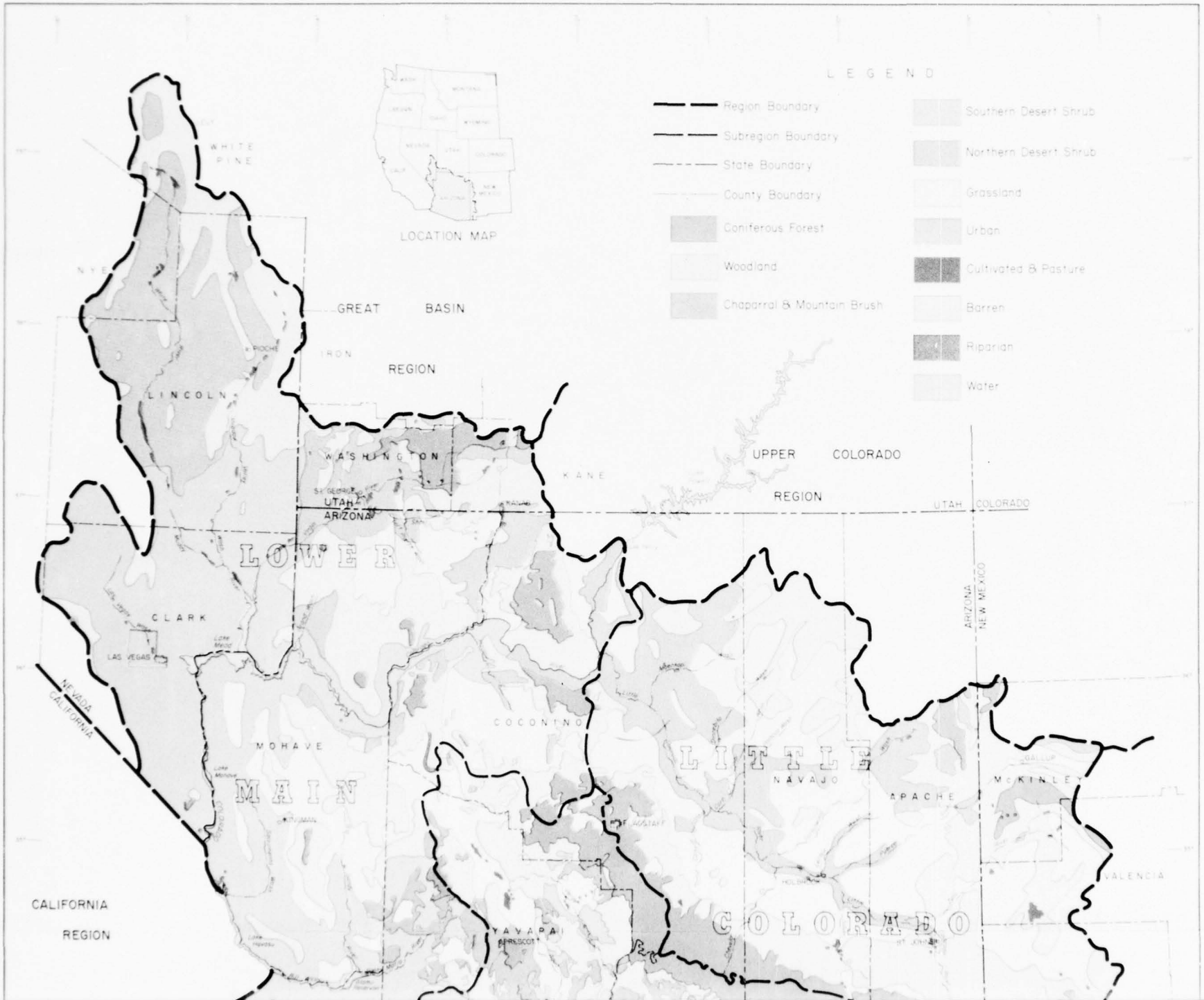
COMPREHENSIVE FRAMEWORK STUDY

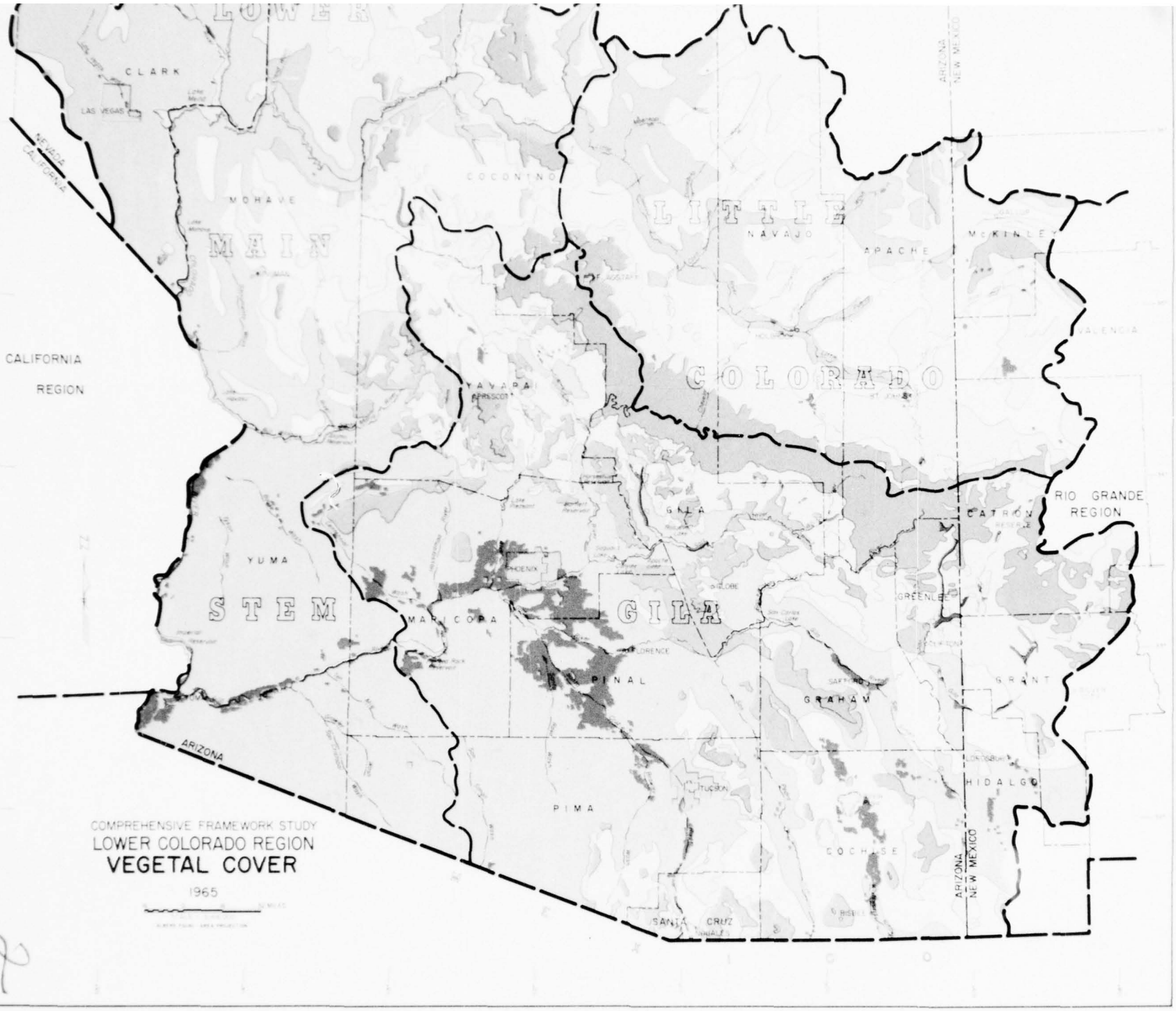
LOWER COLORADO REGION

LAND OWNERSHIP & ADMINISTRATION

1965

M7-S-2433A-N


LEGEND
Region Boundary
Subregion Boundary
State Boundary
County Boundary
Coniferous Forest
Woodland
Chaparral & Mountain Brush
Southern Desert Shrub
Northern Desert Shrub
Grassland
Urban
Cultivated & Pasture
Barren
Riparian
Water
LOCATION MAP
GREAT BASIN REGION
UPPER COLORADO REGION
CALIFORNIA REGION
LOWER
MAIN
LITTLE
COLORADO
WHITE PINE
LINCOLN
CLARK
LAS VEGAS
NEVADA
CALIFORNIA
IRON
WASHINGTON
ST. GEORGE
UTAH
ARIZONA
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
GALLUP
ARIZONA
NEW MEXICO
UTAH
COLORADO
YAVAPAI
PRESCOTT
VALENCIA



COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION

VEGETAL COVER

1965

M7-S-243B-N

Land areas by resource groups are depicted by Figure 5.

The Region's cropland area contained about 1.8 million acres of which 98 percent was classified as irrigated in 1965. Of the total cropland area, 1.6 million acres were actually available for crop production. The nonirrigated cropland, 31,000 acres in 1965, is located on lands above 4000 feet elevation where annual precipitation of 16 inches or more is usual.

The total area used for grazing by domestic livestock in 1965 was about 76 million acres, which is about 84 percent of the total land area of the Region.

There are 30 million acres of forest and woodland in the Region, of which 5.5 million acres are classed as commercial timber producing lands. In general, the forests occur above 4000 feet in elevation.

The forest lands of the Region contribute an average of about 2.8 million acre-feet of water annually to streamflow and important but unmeasured quantities of water to underground aquifers. About 31,000 acres of regional lands are included in classified watersheds to provide high quality domestic water to local municipalities.

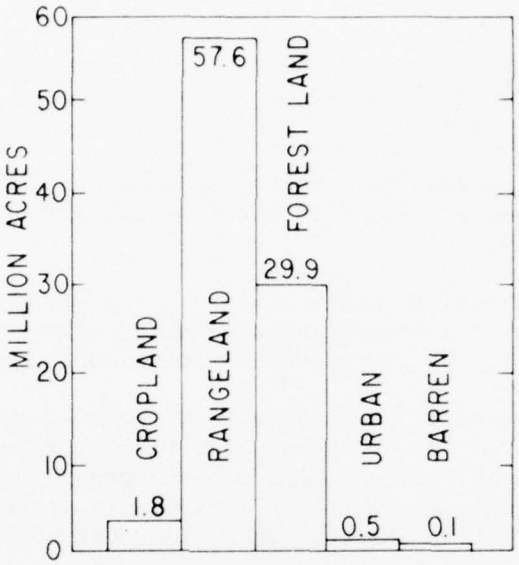
Urban and industrial uses occupied about 513,000 acres in the Region in 1965. In 1965, more than 68 million acres were used for outdoor recreation, although there were only 5.5 million acres of designated recreation lands.

Most of the Region provides habitat for game and nongame species of fish and wildlife. It is estimated that 76 million acres contribute materially as important habitat for wildlife, and most are open to fishing and hunting.

Of the total habitat, 3.2 million acres were managed primarily for wildlife in 1965. Thirty-two million acres, both publicly and privately owned, are administered under the principle of multiple-use with fish and wildlife being one of the important resources. The remaining acreage is important and productive in varying degrees to many game and nongame species.

Thirteen areas, comprising nearly 1.4 million acres, were designated for wilderness management in 1965, while 660,000 acres were used for transportation and utility purposes. A large portion of the 4.1 million acres used for military purposes is desert or semiarid mountainous terrain, although some of this land was once productive as rangeland or cropland. The actual acreage used for mineral production in 1965 was only 75,000 acres.

FIGURE 5
LAND AREA BY RESOURCE GROUPS-1965



LAND TREATMENT AND MANAGEMENT

Over the past several years, significant advances have been made in land treatment and management practices and techniques by land owners and public land managers. They strive for improvement of water yield, improvement of water quality, and the reduction of erosion, sedimentation, and flooding. Such programs also increase livestock and wildlife forage, improve timber production, and enhance recreation and esthetic values. Management techniques and practices are expected to improve and intensify.

Public Lands

About 64 percent of the Region's land is in public ownership. The national forests, the public domain land, and the state land are all managed under the principle of multiple-use. The remainder of the public lands is managed for a primary objective, such as wildlife, parks, defense, etc.

The public land administering agencies, universities, and public and semipublic organizations are actively carrying out management research and field trials throughout the Region. These research

activities provide improved methods for treatment and management of all water and related land resources, uses, and values.

Privately Owned Lands

The primary objective of management measures on privately owned lands (36 percent of the Region) is to improve income and to protect and/or restore the land and water resources of the immediate area.

Soil conservation districts, organized under state law, utilize technical and financial assistance from various public and quasi-public agencies and organizations. They work directly with individual owners and/or operators and cooperate with agencies administratively responsible for public lands within the district boundaries.

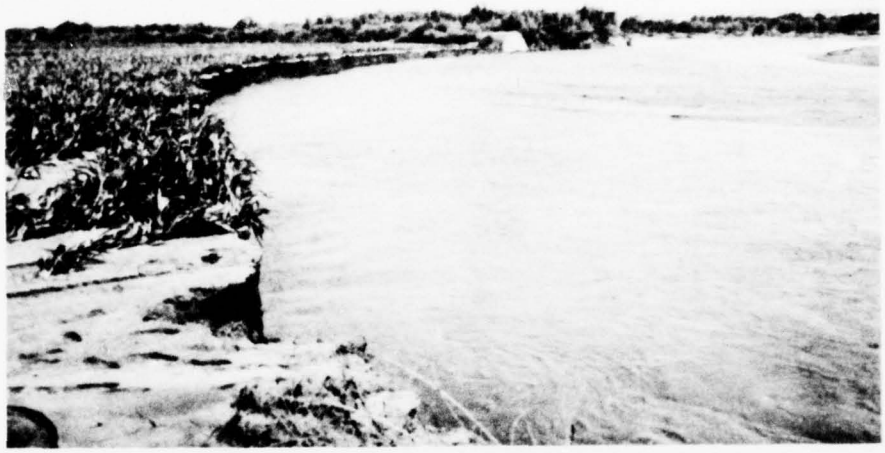
Progress to 1965

There is no accurate method for determining what portion of the total area had received adequate land treatment and management by 1965. On an equivalent acre basis, using present standards, sufficient measures had been installed to adequately treat about 37 percent of the irrigated cropland in the Region. While most public forest and rangelands utilized by domestic livestock are under some form of improved livestock management, only 15 percent of these lands benefit from completed management programs. Less than 10 percent of the commercial timberland in the Region has been developed and is being managed for the maximum production of timber products. An estimated 25 percent of the measures and treatment needed for the efficient development and management of urban and other lands have been provided for based upon the 1965 needs of the people. In nearly all cases, the measures and practices meeting the standards in 1965 are expected to be inadequate in the near future because of improved technology and a limited useful life.

Management programs, developments, and practices that have been installed on public and private lands as of 1965 include measures for reducing erosion and sedimentation, and controlling runoff. Also installed are measures for improved livestock forage and timber production. In 1965, most land received some degree of wildfire protection. Vegetative and resource management have been provided on over 2,500 square miles of forest land for increased water yield and livestock forage.

Watershed Management Problems

More intensive use of the land resources has created a multitude of watershed management problems including: increased soil erosion, accelerated sediment production, reduced productivity, increased flood damage, and degraded water quality. There is a need to treat high yielding mountain watershed lands to increase and regulate water yield in order to help fulfill



Streambank Erosion

Sediment Damage

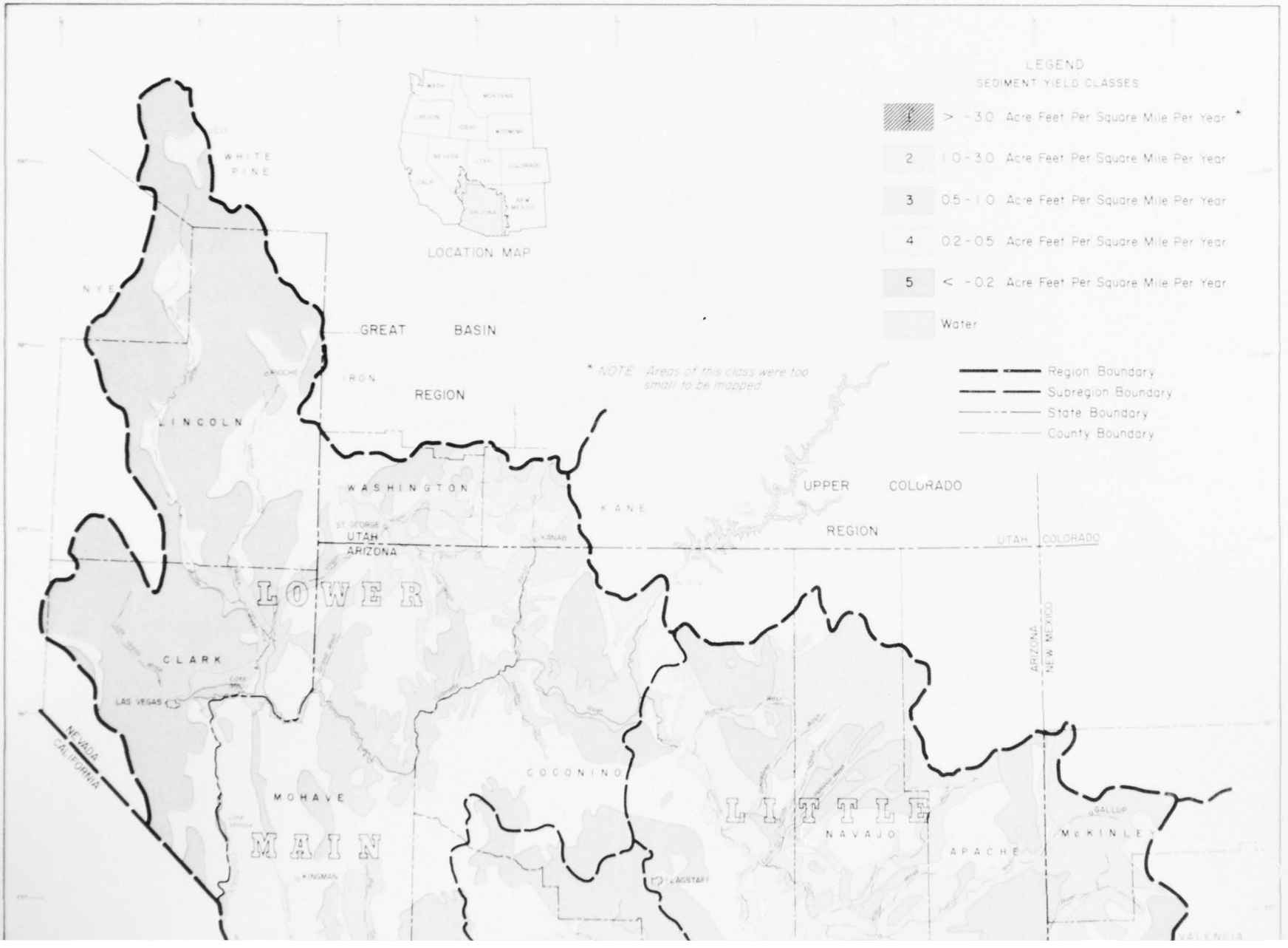
the ever-increasing water requirements. This requires carefully coordinated management practices that will increase water yield, and simultaneously minimize impacts on or enhance other important resource values. Sixty percent of the land needs land treatment and management for erosion control and sediment yield reduction. The 1965 average annual erosion damage was estimated to be $6.7 million. Of this, $3.5 million was from loss in land productivity, $0.2 million was from land lost from streambank erosion and gullies, $1.1 million was damage to improvements and equipment, and $1.9 million was damage to public facilities.

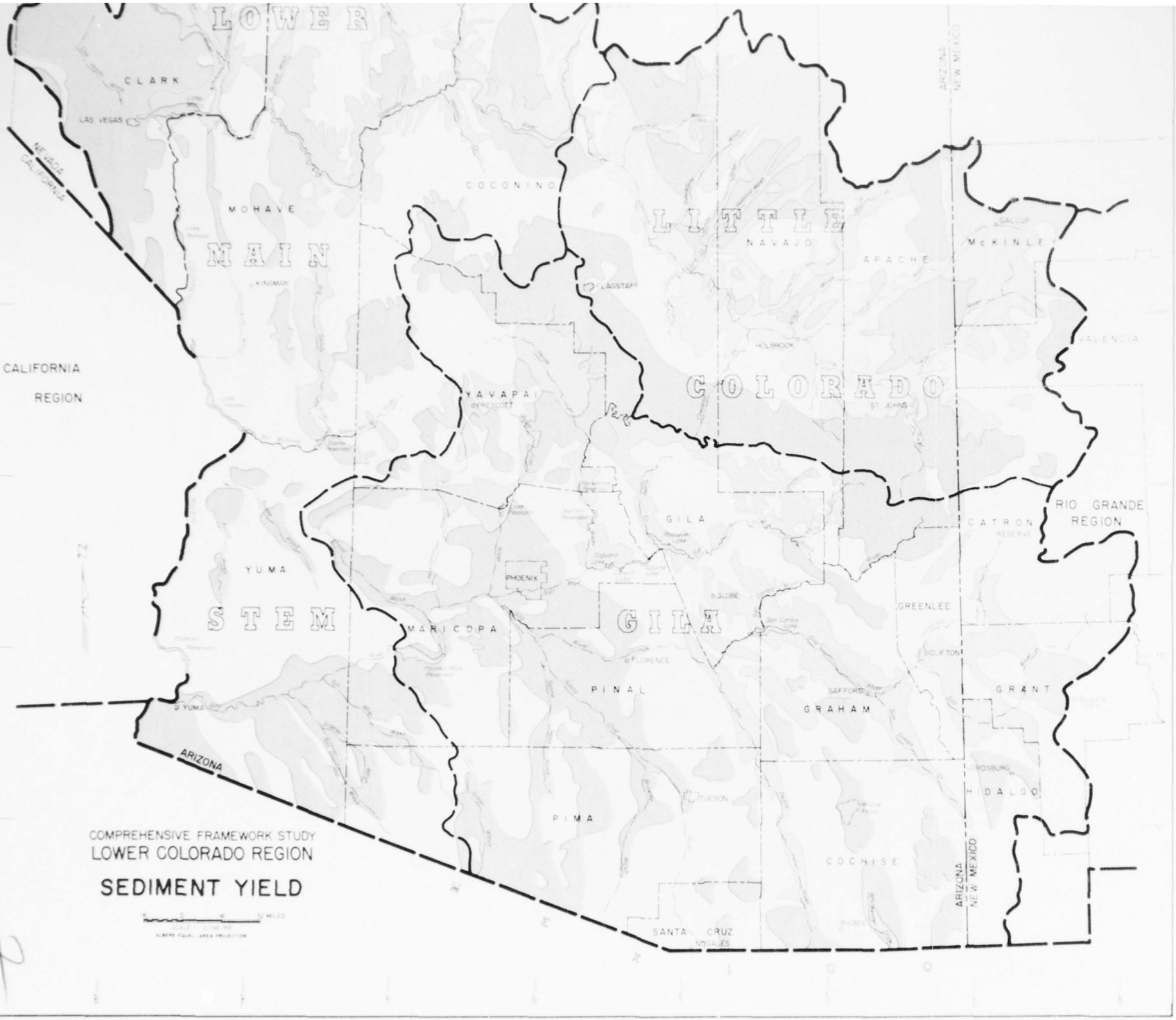
Sediment yield is the product of erosion and the efficiency of the streams' transport ability. The **Sediment Yield Map**, following page 34, shows the general location of the four sediment yield classes which occur in the Region.

Danger from wildfire on the forest and rangelands usually is present some place in the Region during every month of the year. Problems and responsibilities for wildfire protection and control are multiplying due to the development of small communities, expanding urban, and public use developments scattered throughout the forest and rangelands. The average annual burned area was about 45,000 acres in 1965, with a resulting damage of $5.7 million.

Burned area in chapparal.

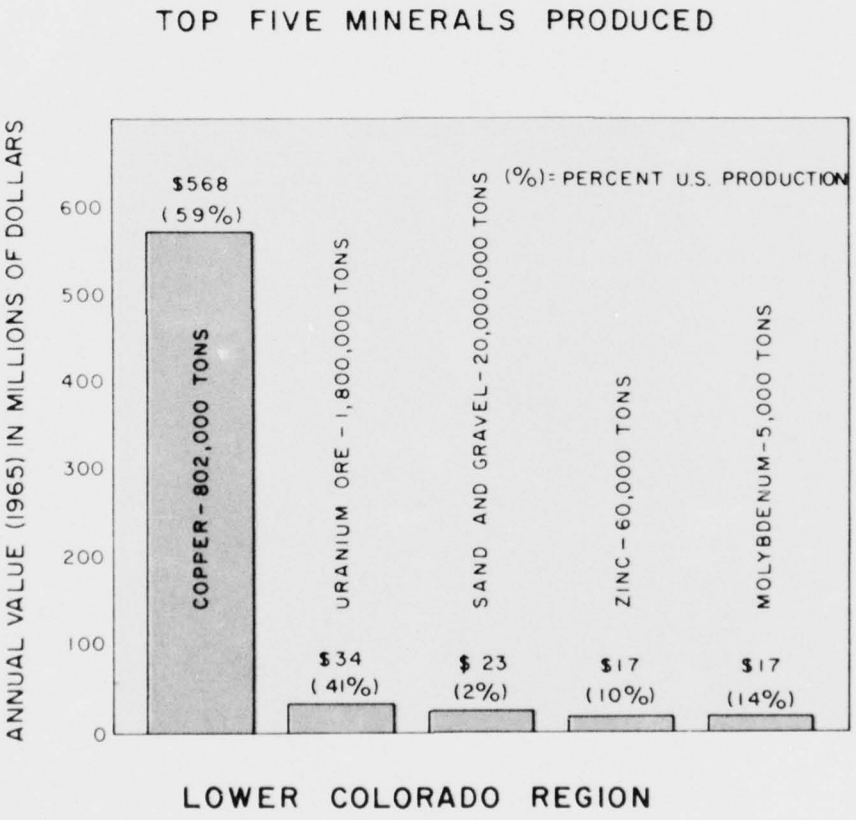
Floodwater and sediment damage to irrigation canal.


LEGEND
SEDIMENT YIELD CLASSES
1 > - 3.0 Acre Feet Per Square Mile Per Year *
2 1.0 - 3.0 Acre Feet Per Square Mile Per Year
3 0.5 - 1.0 Acre Feet Per Square Mile Per Year
4 0.2 - 0.5 Acre Feet Per Square Mile Per Year
5 < - 0.2 Acre Feet Per Square Mile Per Year
Water
Region Boundary
Subregion Boundary
State Boundary
County Boundary
* NOTE: Areas of this class were too small to be mapped.
LOCATION MAP
GREAT BASIN REGION
UPPER COLORADO REGION
LOWER MAIN
LITTLE
WHITE PINE
NYE
LINCOLN
CLARK
LAS VEGAS
NEVADA
CALIFORNIA
IRON
WASHINGTON
ST. GEORGE
UTAH
ARIZONA
KANAB
KANE
MOHAVE
KINGMAN
COCONINO
FLAGSTAFF
NAVAJO
APACHE
McKINLEY
GALLUP
GRANT
VALENCIA
UTAH
COLORADO
ARIZONA
NEW MEXICO


LOWER
CLARK
LAS VEGAS
NEVADA
CALIFORNIA
MOHAVE
MAIN
COCONINO
LITTLE
NAVAJO
APACHE
McKINLE
GALLUP
ARIZONA
NEW MEXICO
FLAGSTAFF
HOLBROOK
VALENCIA
CALIFORNIA
REGION
YAVAPAI
PRESCOTT
COLORADO
ST JOHNS
GILA
CATRON
RESERV
RIO GRANDE
REGION
YUMA
STEM
PHOENIX
GLOBE
GREENLEE
MARICOPA
GILA
FLORENCE
CLIFTON
PINAL
SAFFORD
GRANT
YUMA
GRAHAM
ARIZONA
ROSBURG
HIDALGO
TUCSON
PIMA
COCHISE
ARIZONA
NEW MEXICO
SANTA CRUZ
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
SEDIMENT YIELD
M7-S-2431D-N

MINERAL PRODUCTION

Currently, copper is "queen" of minerals in the Lower Colorado Region, with uranium ore being the second in dollar value and sand and gravel being third. The following graph depicts the quantities and values of the major minerals produced in the Region in 1965 and the percents of total United States production:



In 1965, about 105,000 acre-feet of water were withdrawn for mineral production, of which about 51,000 acre-feet were consumed. About 92 percent of the water consumed by the mineral industry was used for production of copper and its byproducts: gold, silver, and molybdenum.

FLOOD CONTROL

Flood control and flood damage-prevention consist of structural measures and nonstructural programs performed by Federal agencies, states, and local organizations. Structural measures include reservoirs, channel improvements, levees and dikes, channel stabilization, and sediment control. Nonstructural programs include flood forecasting and flood plain regulations.

Flood Control Structures

The locations of 25 of the more significant existing flood control and flood damage-prevention projects are shown on the map following page 38. Many other smaller projects provide varying degrees of local flood protection, although they are not shown on the map. Floodwater detention basins and reservoirs with flood control storage existing in the Region in 1965 have a total storage capacity of 10.7 million acre-feet. Also existing in 1965 were 143 miles of levees and 120 miles of channel improvements.

In addition to the flood control structures described above, land treatment and management practices under existing programs, while smaller in scope, have significant offsite effects in reducing erosion and sedimentation, controlling runoff, and prolonging the life of detention and storage facilities.

Flood Forecasting

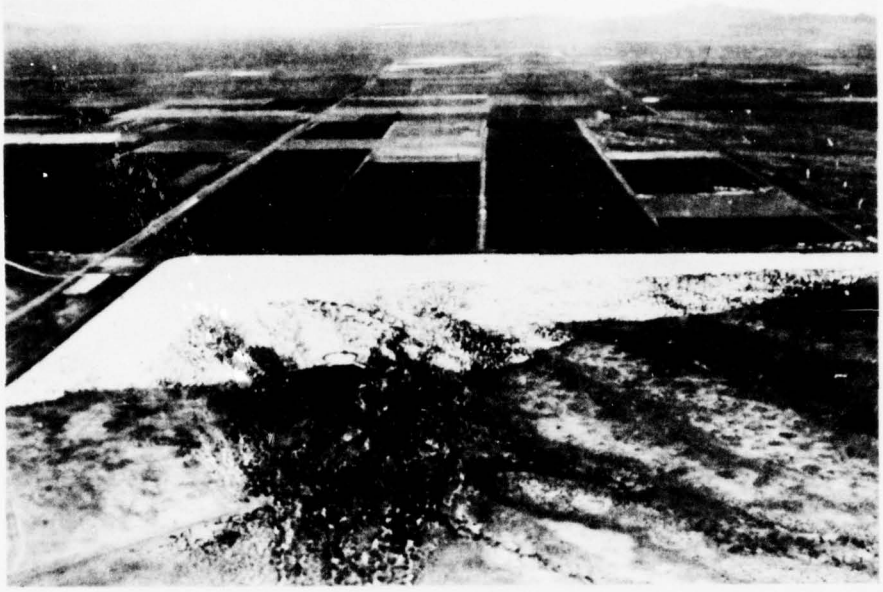
Currently, there are 14 river gage locations within the Region for which forecasts of runoff are made. Flood warning systems have been developed and affected urban and agricultural areas are alerted of impending flood situations.

Flood Plain Regulations

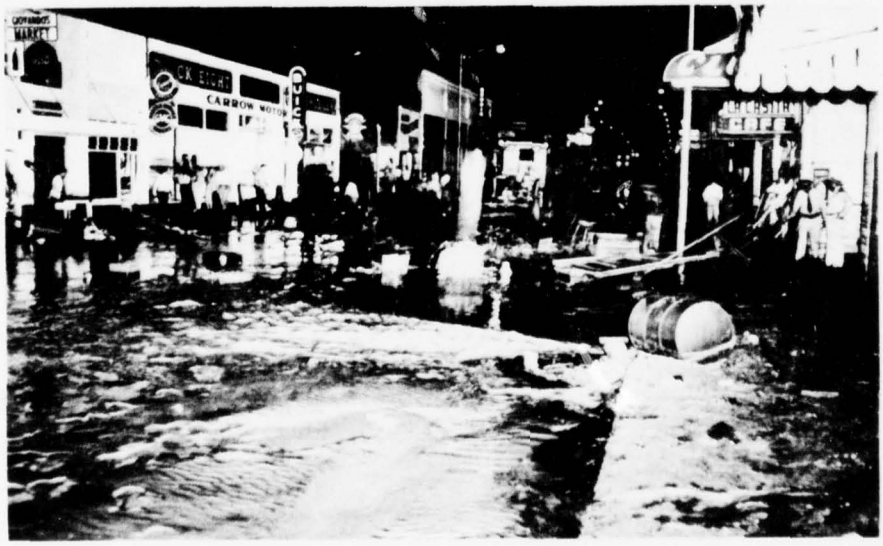
Flood plain regulations would limit the types of development and use of lands in flood plains, thus limiting potential damages in flood-prone areas. Guidelines for establishing such regulations have been made available, but have been adopted by very few communities.

Accomplishment of Existing Flood Control Program

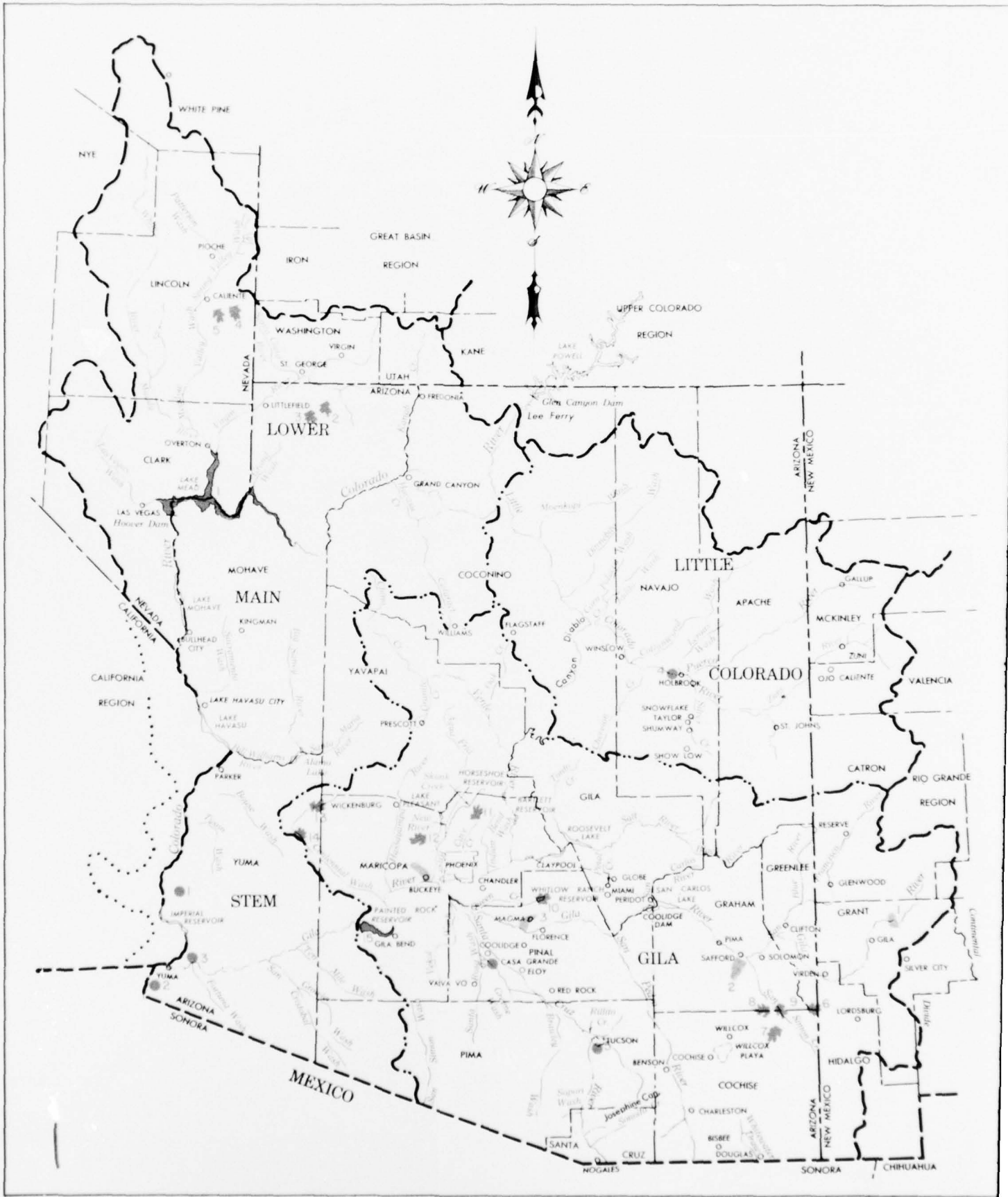
The existing flood control program had prevented an estimated $110.4 million in flood damages through 1965, based on historic flood data. Protection has been provided to about 238 miles of rivers and streams and 734,000 acres of land. Based on the 1965 economic conditions and the existing flood control program, residual damages are estimated to total



Floodwater retarding structure - Magma Watershed - September 1966



Flooding at Globe, Arizona, July 1954
(Photo by Norman's Studio, Globe, Arizona)


WHITE PINE
NYE
LINCOLN
PIOCHE
CALIENTE
IRON
GREAT BASIN
REGION
WASHINGTON
VIRGIN
ST. GEORGE
KANE
UTAH
ARIZONA
NEVADA
UPPER COLORADO
REGION
LAKE POWELL
FREDONIA
Glen Canyon Dam
Lee Ferry
LOWER
LITTLEFIELD
OVERTON
CLARK
LAKE MEAD
LAS VEGAS
Hoover Dam
GRAND CANYON
Colorado River
ARIZONA
NEW MEXICO
MOHAVE
MAIN
COCONINO
LITTLE
NAVAJO
APACHE
GALLUP
MCKINLEY
ZUNI
LAKE MOHAVE
KINGMAN
BULLHEAD CITY
NEVADA
CALIFORNIA
WILLIAMS
FLAGSTAFF
WINSLOW
Little Colorado River
Canyon
Diablo
HOLBROOK
COLORADO
OJO CALIENTE
VALENCIA
CALIFORNIA
REGION
LAKE HAVASU CITY
LAKE HAVASU
YAVAPAI
PRESCOTT
SNOWFLAKE
TAYLOR
SHUMWAY
ST. JOHNS
SHOW LOW
CATRON
RIO GRANDE
REGION
PARKER
Colorado River
HORSESHOE RESERVOIR
ROOSEVELT LAKE
GILA
WICKENBURG
LAKE PLEASANT
RESERVE
YUMA
MARICOPA
PHOENIX
CHANDLER
BUCKEYE
CLAYPOOL
GLOBE
GREENLEE
GLENWOOD
WHITLOW RANCH RESERVOIR
MIAMI
PERIDOT
SAN CARLOS LAKE
STEM
IMPERIAL RESERVOIR
PAINTED ROCK RESERVOIR
GILA BEND
MAGMA
COOLIDGE DAM
GRAHAM
GRANT
CLIFTON
FLORENCE
COOLIDGE
PINAL
CASA GRANDE
ELOY
PIMA
SAFFORD
SOLOMON
GILA
GILA
VAIVA VO
RED ROCK
VIRDEN
SILVER CITY
LORDSBURG
YUMA
ARIZONA
SONORA
MEXICO
TUCSON
WILCOX
WILCOX PLAYA
BENSON
COCHISE
HIDALGO
PIMA
COCHISE
Josephine Canyon
CHARLESTON
BISBEE
DOUGLAS
SANTA CRUZ
NOGALES
ARIZONA
NEW MEXICO
SONORA
CHIHUAHUA

LEGEND

- REGION BOUNDARY
- SUBREGION BOUNDARY
- STATE BOUNDARY
- COUNTY BOUNDARY
- COLORADO RIVER DRAINAGE
- (U) UPSTREAM PROJECT
- (D) DOWNSTREAM PROJECT

EXISTING (1965) PROJECTS

RESERVOIR WITH FLOOD CONTROL

1. LAKE MEAD	(D)
2. FLAT TOP	(U)
3. IVERSON	(U)
4. MATHEWS CANYON	(U)
5. PINE CANYON	(U)
6. RAILROAD WASH	(U)
7. CREIGHTON	(U)
8. H-X	(U)
9. SAN SIMON	(D)
10. WHITLOW RANCH	(U)
11. CAVE CREEK	(U)
12. MOMICKEN	(U)
13. UPPER CENTENNIAL	(D)
14. LOWER CENTENNIAL	(D)
15. PAINTED ROCK	(D)

LEVEE AND CHANNEL PROJECTS

1. COLORADO RIVER	(D)
2. YUMA VALLEY	(D)
3. GILA RIVER	(D)
4. HOLBROOK	(D)
5. TUCSON DIV.	(U)
6. GREENE WASH	(D)

WATERSHED PROJECTS *

1. ARROYOS NO. 1	(U)
2. FRYE-STOCKTON	(U)
3. MAGMA	(U)
4. WHITE TANKS	(U)

* THESE PROJECTS INCLUDE RESERVOIRS, CHANNELS, LEVEES, AND RELATED LAND TREATMENT AND MANAGEMENT MEASURES.

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION

EXISTING IMPROVEMENTS FOR FLOOD CONTROL AND RELATED PURPOSES

SCALE 20 0 20 40 60 MILES

2

nearly $41 million annually, of which $22 million are agricultural and $19 million are nonagricultural damages.

IRRIGATION AND DRAINAGE

Irrigation

In base year 1965, there were approximately 1,530,000 acres of land developed for irrigation in the Lower Colorado Region. About 370,000 of these developed acres were out of production because of insufficient water supplies, poor water quality, high pumping costs, and other factors. Of the remaining 1,190,000 acres irrigated, a portion was plagued by similar problems. About 125,000 acres were cropped more than once in 1965. See map following page 42.

Of the 1,315,000 acres planted in the Region in 1965, only about 280,000 acres depend entirely on surface waters. About 417,000 acres require supplemental ground water and 618,000 acres depend entirely on a ground-water source of supply. Average annual irrigation withdrawal rates of over 6 acre-feet per acre are common and, in some cases, withdrawals greater than 10 acre-feet per acre are required. Seven crops, accounting for nearly 95 percent of the total harvested acreage under irrigation in the Region in 1965, are shown in the following tabulation:

Crop	Acreage
Alfalfa	208,000
Barley	170,000
Citrus	39,000
Cotton	345,000
Pasture	92,000
Sorghum	186,000
Vegetables	75,000

There is a very intense recycling and reuse of irrigation runoff and percolating water which result in increased concentrations of dissolved salts in these waters. Consequently, damaging concentrations of salts are being built up in some soils, especially in the lower elevations of some areas of the Region. Ground-water quality is progressively deteriorating, making it increasingly more difficult to maintain an acceptable salt balance.

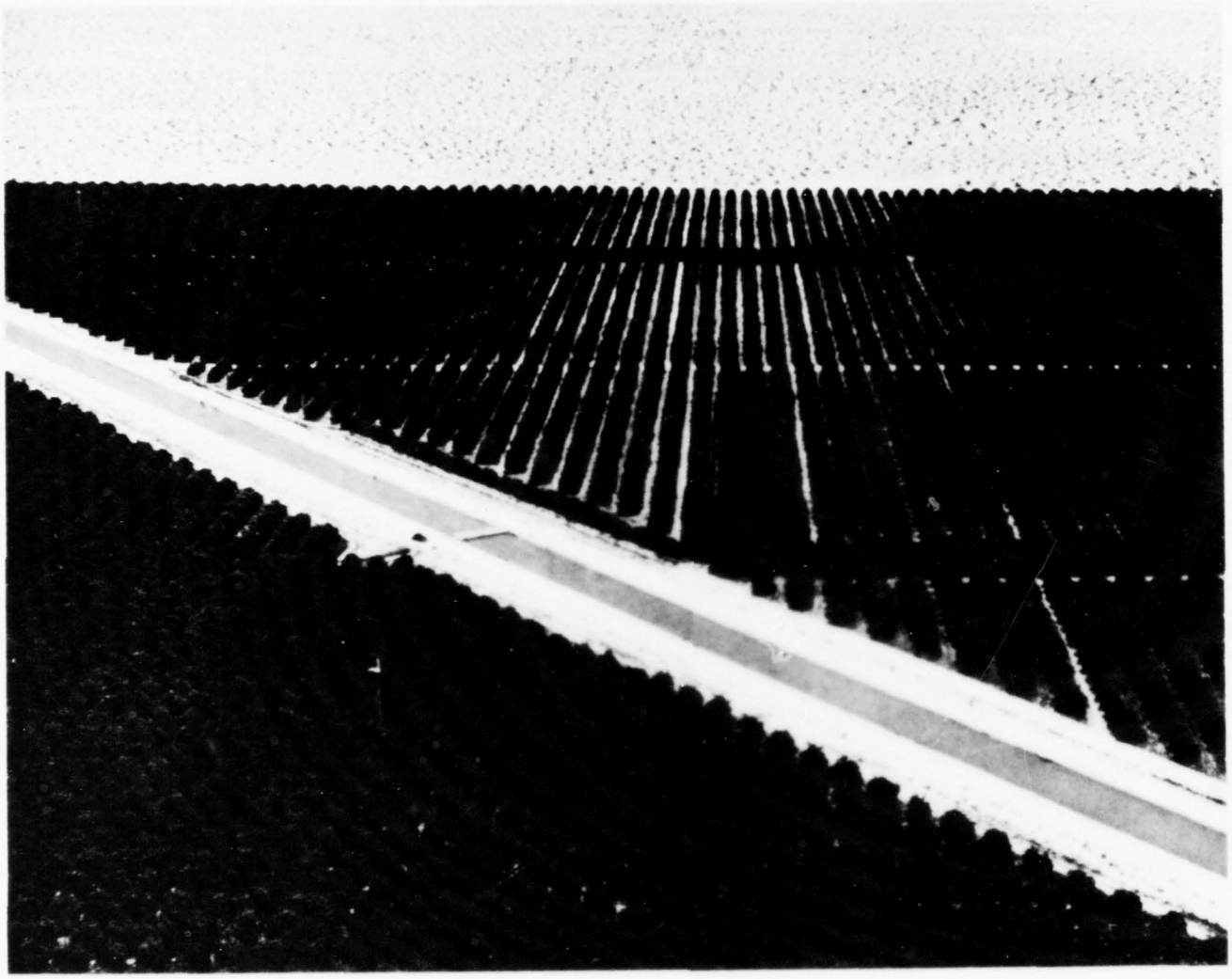
In 1965, about 7.7 million acre-feet of water were withdrawn for irrigation use, of which 4.7 million acre-feet were pumped from underground sources and 3.0 million acre-feet were diverted from surface sources.

Drainage

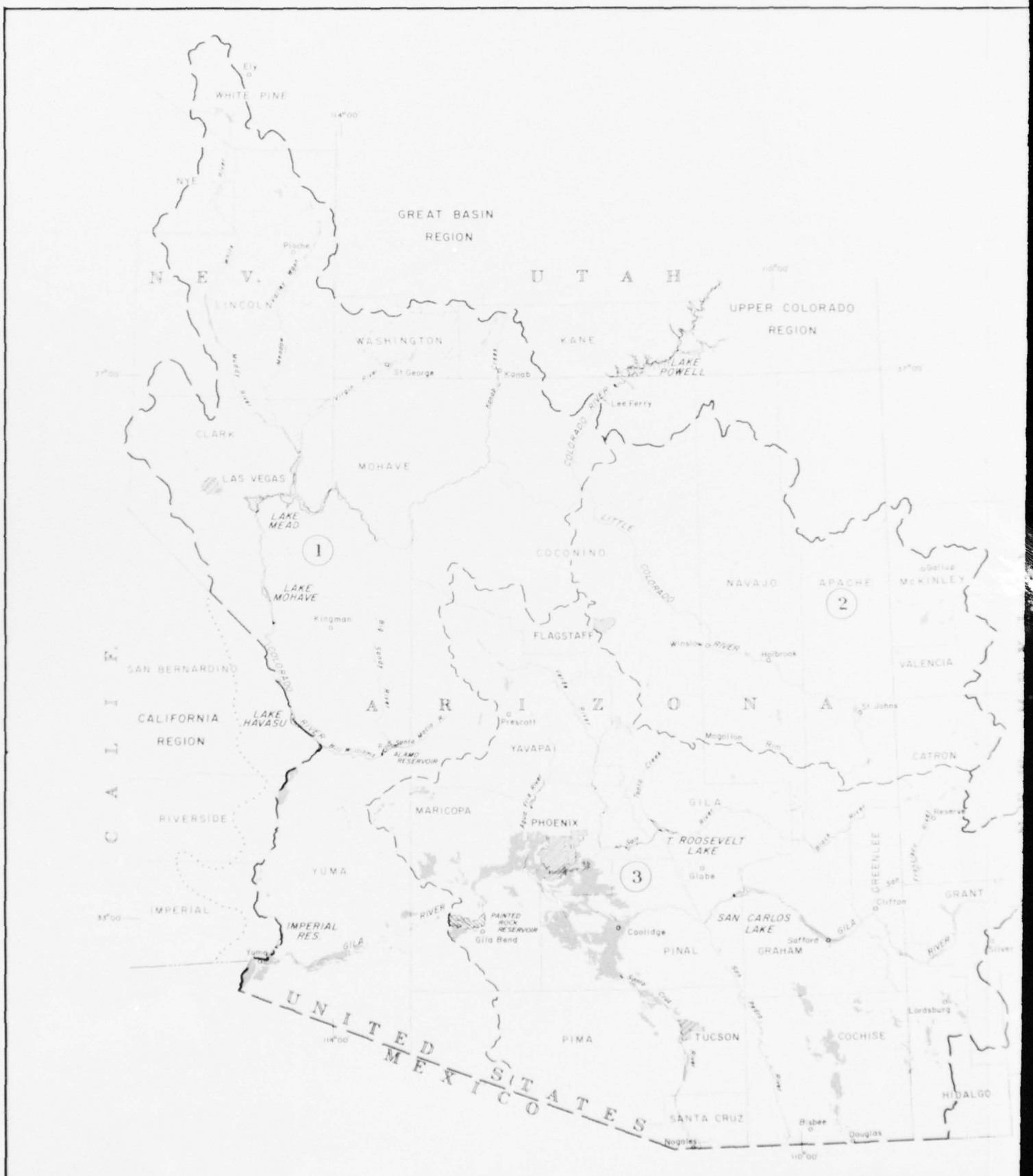
Drainage problems in the Lower Colorado Region are generally caused by three factors: poor management of irrigation water, unfavorable drainage characteristics of the subsoil, or unfavorable topography of the area being irrigated. Each of these factors, singly or in combination with others, causes water to accumulate in and/or on the soil. As a result, the soil becomes waterlogged, thus, plant production is reduced. Much progress has been made in the correction of drainage problems, but most of the land that has been irrigated has had some drainage problems.

Typical row irrigation operation.

Harvesting Citrus



Irrigated Citrus Groves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UTAH
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REGION
WHITE PINE
Ely
NYE
Pioche
LINCOLN
WASHINGTON
St George
KANE
Kanab
LAKE
POWELL
Lee Ferry
CLARK
LAS VEGAS
MOHAVE
LAKE
MEAD
LAKE
MOHAVE
Kingman
COCONINO
FLAGSTAFF
NAVAJO
APACHE
McKINLEY
Gallup
Holbrook
VALENCIA
SAN BERNARDINO
CALIFORNIA
REGION
LAKE
HAVASU
ARIZONA
Prescott
YAVAPAI
Magellon
CATRON
RIVERSIDE
MARICOPA
PHOENIX
GILA
T ROOSEVELT
LAKE
Globe
YUMA
IMPERIAL
IMPERIAL
RES.
PAINTED
ROCK
RESERVOIR
Gila Bend
Coolidge
SAN CARLOS
LAKE
Safford
GRAHAM
GREENLEE
Clifton
GRANT
PINAL
PIMA
TUCSON
COCHISE
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SANTA CRUZ
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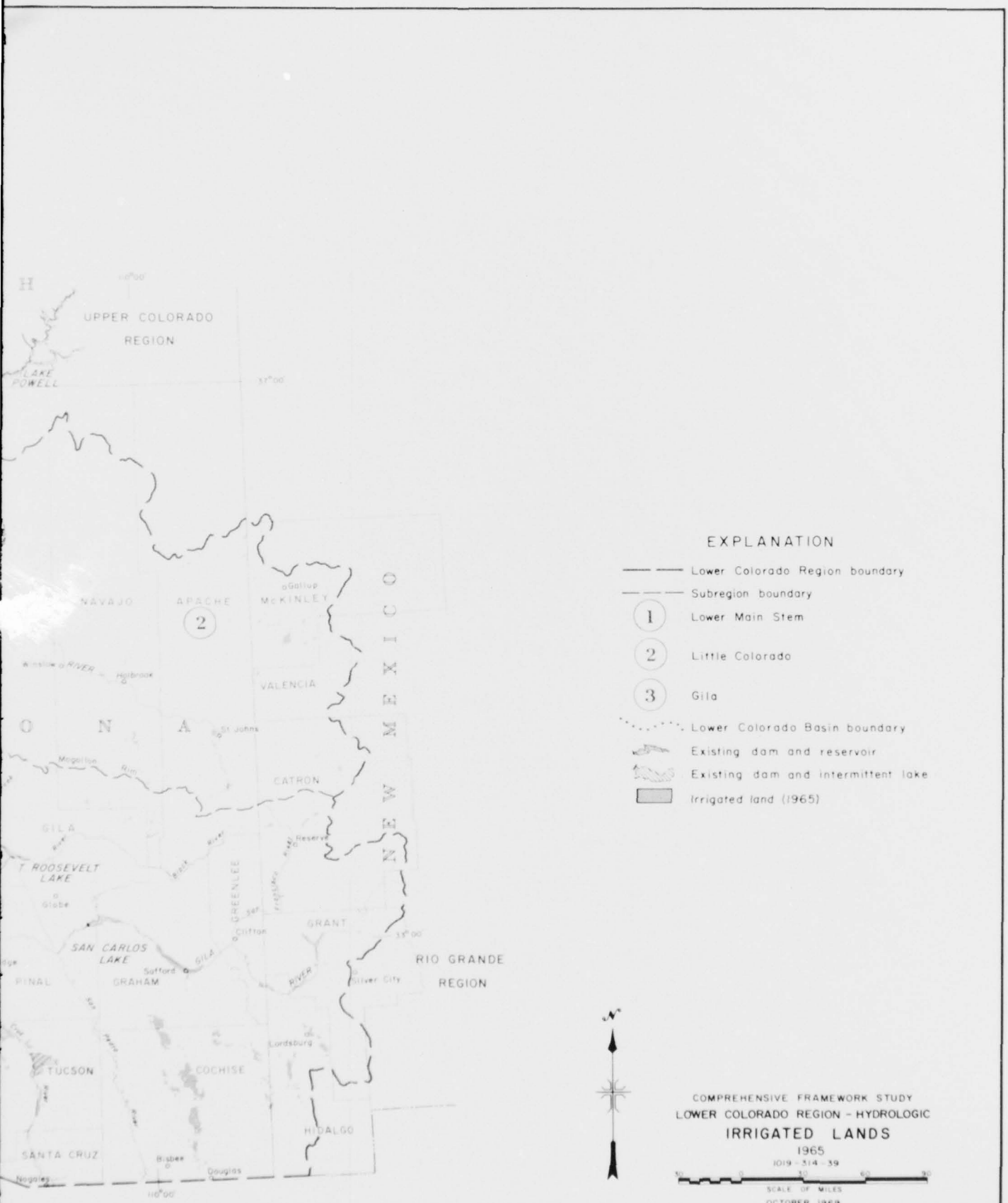
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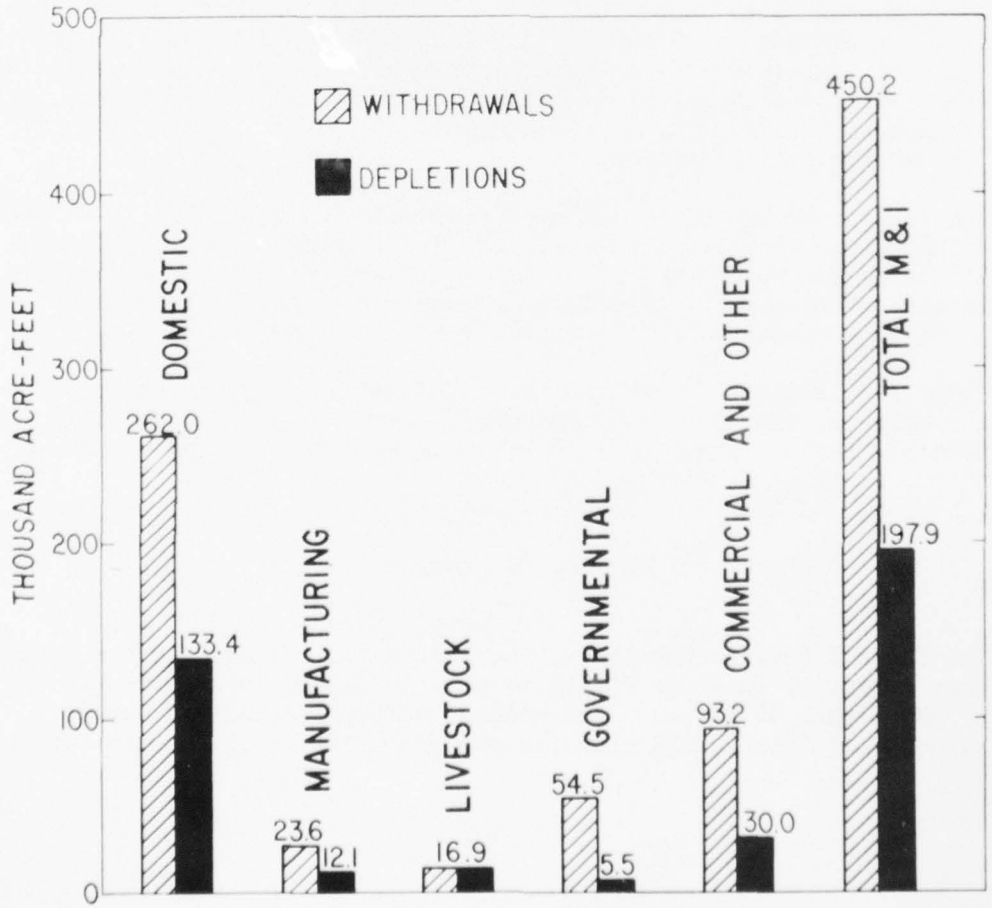
GREENLEE
Clifton
GRANT
SAN CARLOS
LAKE
Safford
GILA
RIVER
Silver City
RIO GRANDE
REGION
PINAL
GRAHAM
Lordsburg
TUCSON
COCHISE
HIDALGO
SANTA CRUZ
Bisbee
Douglas
Nogales
110°00'
EXPLANATION
Lower Colorado Region boundary
Subregion boundary
1 Lower Main Stem
2 Little Colorado
3 Gila
Lower Colorado Basin boundary
Existing dam and reservoir
Existing dam and intermittent lake
Irrigated land (1965)
N
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION - HYDROLOGIC
IRRIGATED LANDS
1965
1019-514-39
SCALE OF MILES
OCTOBER 1969

MUNICIPAL AND INDUSTRIAL WATER

Water Use

Domestic, manufacturing, livestock, governmental, commercial, and other municipal and industrial water uses in the Lower Colorado Region had estimated withdrawal requirements of 450,200 acre-feet in 1965. The estimated depletion requirement for these uses was 197,900 acre-feet. Water requirements exhibit definite seasonal variations, with the peak use occurring during the summer months. Distribution of withdrawals and depletions by uses is shown on Figure 6.

FIGURE 6
MUNICIPAL AND INDUSTRIAL WATER USE - 1965



In 1965, the average domestic withdrawal rate was 129 gallons per capita per day, of which 65 gallons per capita per day were depleted. Withdrawal requirements for domestic uses vary from a maximum during the summer months of about 170 percent of the average monthly requirement to a minimum during the winter months of about 40 percent of the average monthly requirement.

Manufacturing industries require water for cooling, steam generation, process, sanitary, and other uses. Water for cooling and steam generation accounts for about 70 percent of the total manufacturing water use in the Region. Manufacturing industrial water demands vary generally from a maximum of 120 percent of the average monthly requirement during the summer months to a minimum of 80 percent of the average monthly requirements during the winter months.

Livestock water requirements depend upon climatic factors; species, age, and condition of the animal; nature of the diet; and upon water management practices. Maximum water requirements generally occur during the month of August and amount to 125 percent of the average monthly requirement.

Governmental water depletions were about 10 percent of governmental withdrawal requirements. Some of the governmental uses of water include supplies for: public buildings such as post offices, schools, hospitals, and office buildings; military installations; watering public lawns, parks, and golf courses; fire control; street cleaning; public swimming pools; and various research activities.

The depletions by commercial and other water uses were about 32 percent of the withdrawal requirements. Commercial water uses vary from a maximum during the summer months of 120 to 180 percent of the average monthly withdrawal requirements to a minimum during the winter months of from 50 to 80 percent of the average monthly withdrawal requirement.

Water requirements for the construction industry have been included in the commercial and other uses category. Water uses in the construction industry include dust control, batching of concrete, and various washing processes.

OUTDOOR RECREATION

The Federal Government, through several agencies, assists the states and other interests in their effort to provide outdoor recreation in the Region. More than 94 bureaus, independent offices, agencies, boards, commissions, committees, and councils are presently involved with outdoor

recreation in the country. Most of these are also concerned with recreation in some form in the Lower Colorado Region.

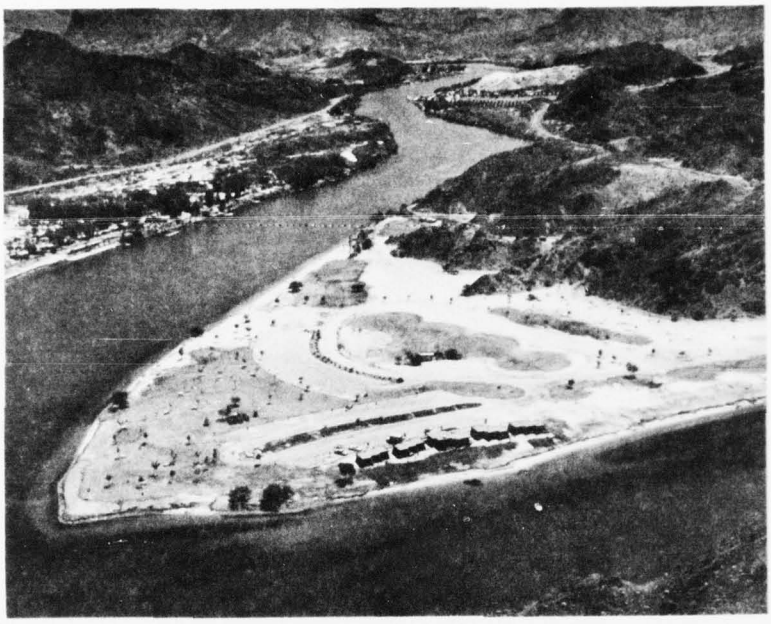
The lands used for outdoor recreation in 1965 within the Region total about 68 million acres and include private as well as public lands. Figure 7, page 47, depicts recreation land and water acreages by subregion and percent of regional acreages. About 218,700 acres of water were available for recreation use in 1965.

Typical Bureau of Land Management developed recreation areas are the Cerbat Mountains area and Crystal Hills in Arizona, and the Red Rocks Recreation Area near Las Vegas, Nevada. A number of concession and permittee operated facilities have been developed by private individuals to provide for water-oriented use along the Lower Colorado River and heavy use is made of many undeveloped areas along the River. Most of the public domain lands used for recreation purposes are the lower elevation desert areas. Except for intensive year-round use along the River, these lands are used for camping, sightseeing, etc. during the fall, winter, and spring when the high country climate is not as inviting for these activities.

The National Forests provided significant amounts of land for recreation use in 1965. The major winter sports areas are within national forests. In the summer, when the desert temperatures rise, forest campgrounds which are located at higher elevations are used to capacity.

The Region encompasses 21 national parks, monuments, and recreation areas which are administered by the National Park Service. Zion National Park in Utah, and Grand Canyon National Park, Saguaro National Monument, and Organ Pipe Cactus National Monument in Arizona, are examples of the scenic splendor available. Coronado National Monument in Arizona, and the Gila Cliff Dwellings National Monument in New Mexico, are preserved as historical monuments. Lake Mead National Recreation Area, which includes Lake Mead with 162,000 surface acres, and Mohave Lake with 28,200 surface acres, was visited by over $3\frac{1}{2}$ million people in 1965.

Typical state parks include the 18,000-acre Valley of Fire State Park, northeast of Las Vegas, Nevada; Buckskin Mountain State Park, along the Colorado River in Arizona; and Dixie State Park in Utah. South Mountain Park, part of the Phoenix park system containing more than 14,000 acres, is one of the world's largest city parks. The park system of Maricopa County, Arizona, contains more than 60,000 acres in 20 separate areas, many of which were undeveloped in 1965.



Highly developed recreation area on Colorado River

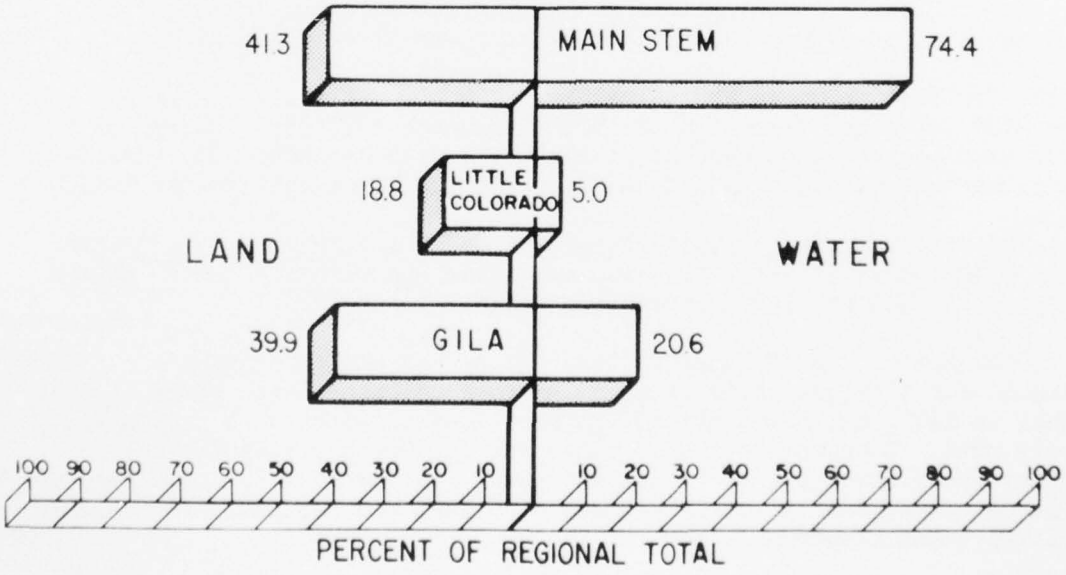
Recreation use of desert area

Six designated wildernesses and 7 primitive areas encompassing nearly 1.5 million acres are located within the Region. The Mazatzal, Superstition, and Galiuro wildernesses are all within 100 miles of more than 50 percent of the Region's population. Private recreation areas include golf courses, dude ranches, summer homes, racetracks, amusement parks, and hunting and fishing preserves. The Indian Trust lands provide 22 percent of the land available and suitable for recreation in the Region.

The 1965 recreation base supplied 138 million days of recreation use, but was deficient by about 44 million recreation days because of location and/or class of recreation resources.

FIGURE 7

RECREATION LAND AND WATER ACREAGE BY SUBREGION



FISH AND WILDLIFE

Fish

About 85 species of fish are known to exist in the Lower Colorado Region. Approximately 25 species provide sport fishing and the others have value as forage fish, as pollution indicators, for scientific investigations, and as a source for a possible commercial fishery.

Fishing waters in the Lower Colorado Region consist of approximately 251,000 acres of streams and manmade impoundments. The fishery is classified into two major categories: the cold water trout fishery of headwaters and impoundments generally above 5500 feet elevation, and the warm water "spiny-rayed" fishery in the streams and impoundments of elevations below 6000 feet.

In 1965, there were 4,217,000 fisherman-days expended in the Lower Colorado Region. This was estimated to be nearly 75 percent of the Region's capacity of 5,723,000 man-days. The available warm water habitat was being fished to 67 percent of its potential. Only an insignificant amount of cold water habitat is not being used to its capacity. Commercial fishing is of minor importance.

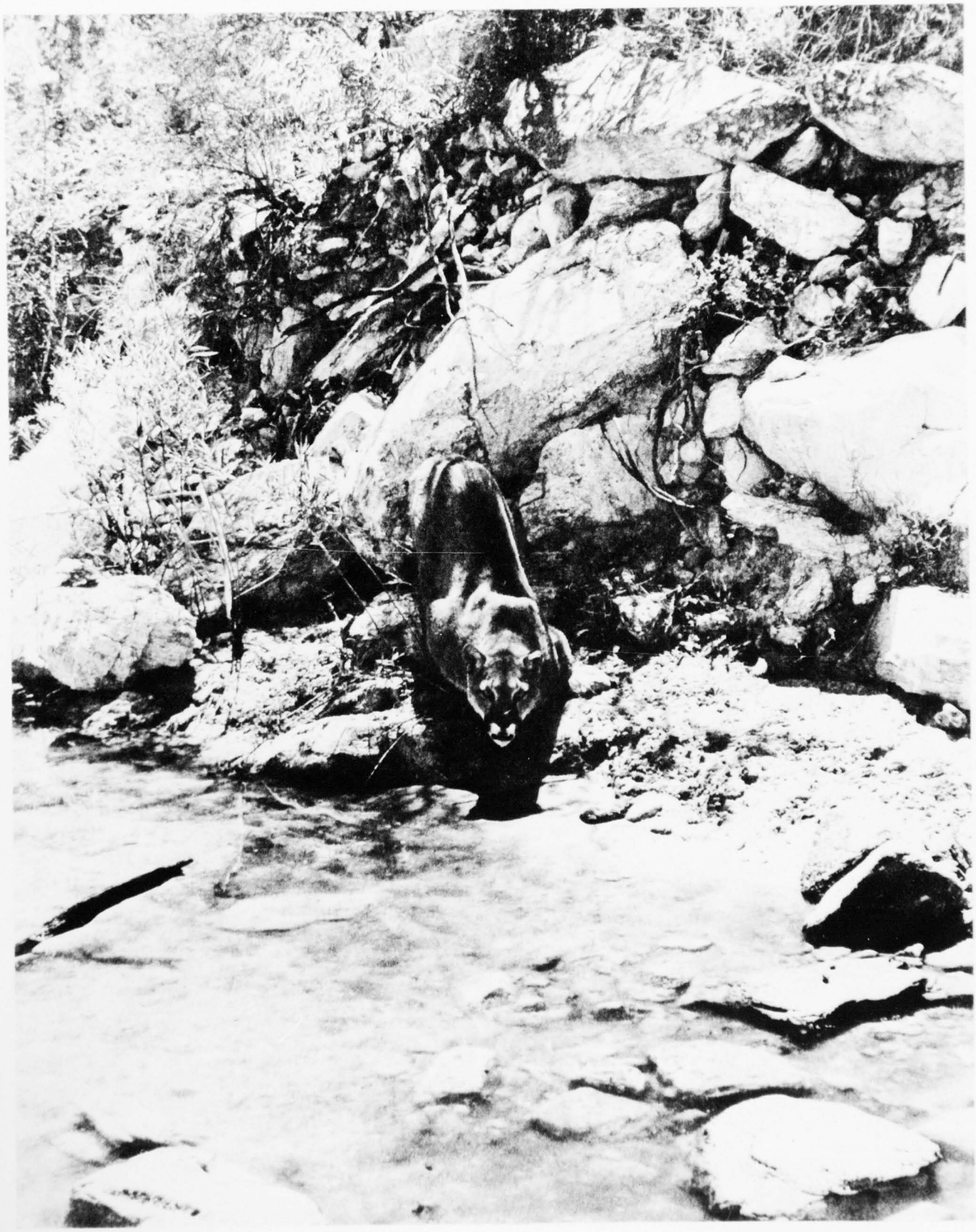
Sport fishery installations and facilities existing in the Lower Colorado Region in 1965 consisted of 97 fishing lakes and 8 fish hatcheries. There were 3 national fish hatcheries and 5 state fish hatcheries that produced approximately 6,700,000 fish, all of which were trout with the exception of 150,000 channel catfish. The Region's production was about 80 percent of the total fish stocked. The remaining 20 percent of the fish stocked were imported from outside the Region.

The primary-purpose public fishing lakes existing in 1965 provided about 6,400 acres of water for fishing. Fish and wildlife installations existing in 1965 are shown on the map following page 52.

Consumptive use of water by fish hatcheries and impoundments designed for fish generally is minor. Based on established water rights in 1965, approximately 10,315 acre-feet of water were consumptively used. Consumptive use of water for fish purposes in the multipurpose water developments is not included. In addition to 6,400 surface acres of water, approximately 425 acres of land were utilized for hatchery facilities and fisherman access.

Wildlife

More than 40 species of wildlife provide hunting ranging from highly prized bighorn sheep and elk to hunting of rabbits and coyotes. There



are also many species of small mammals, birds, and reptiles which provide enjoyment for the nonhunting outdoorsman in nature study and photography.

In relation to hunting, there are 3 wildlife types--big game, upland game (including fur animals and nongame species), and waterfowl.

Big game species are distributed throughout approximately 72 million acres of widely diverse habitat types. Deer are the most abundant. Other important species are the elk, pronghorn antelope, desert bighorn sheep, black bear, turkey, and javelina. The American bison has been preserved in special areas set aside for this purpose.

Upland game species include: mourning dove, white-winged dove, cottontail rabbit, bandtail pigeon, blue grouse, chukar, sage grouse, Gambel's quail, Mearn's quail, scaled quail, Afgan white-winged pheasant, and Albert's squirrel.

Waterfowl habitat within the Region consists of approximately 42,000 acres of native habitat along the permanent streams, manmade lakes, and marshes.

In 1965, there were 1,343,500 man-days of hunting expended in the Lower Colorado Region. Upland game hunting accounted for 56 percent of all hunting. Big game hunting accounted for 39 percent, and waterfowl accounted for the remaining 5 percent of the hunting in the Region.

Designated wildlife developments and facilities managed intensively for wildlife production in 1965 included 49 multiple- and primary-use management areas, 568 habitat improvement facilities, and 20 access roads comprising a total of about 4.2 million acres. Nineteen of the management areas were primarily for big game; 7 areas were for small game; 17 areas were for the protection of waterfowl; and 5 areas were for wildlife in general and associated activities. Locations of designated fish and wildlife facilities existing in 1965 are shown on the map following page 52. An estimated 34,300 acres of developed water for wildlife, mostly waterfowl, were in existence in the Region in 1965. Established water rights exist for the use of approximately 100,000 acre-feet of water on wildlife management areas mostly located along the Colorado River. Consumptive use of water for wildlife purposes in the multiple-use water developments is not included.

ELECTRIC POWER

The total energy requirements of the Region increased at an average rate of 9.5 percent annually during the period from 1955 to 1965. Principal consumer use classifications, residential, commercial, and industrial,

show 1955 to 1965 annual growth rates of 13.4, 11.9, and 10.5 percent, respectively.

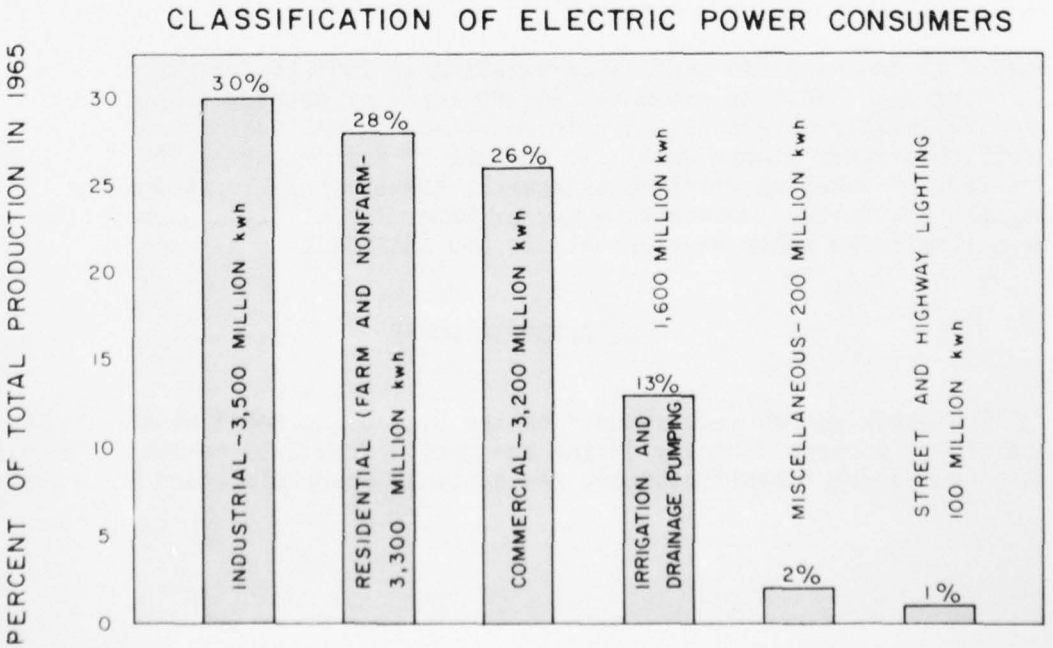
In 1965, the electric utility generating capacity installed and under construction in the Region amounted to more than 4.3 million kilowatts. Total facilities included 14 hydroelectric plants with 1.7 million kilowatts installed capacity, 17 steam-electric plants with installed capacity of 2.5 million kilowatts, and 16 internal combustion electric plants with 0.12 million kilowatts installed capacity. Industrial and miscellaneous power installations consisting of 14 steam plants and 5 internal combustion plants have a total installed capacity of 240 megawatts.

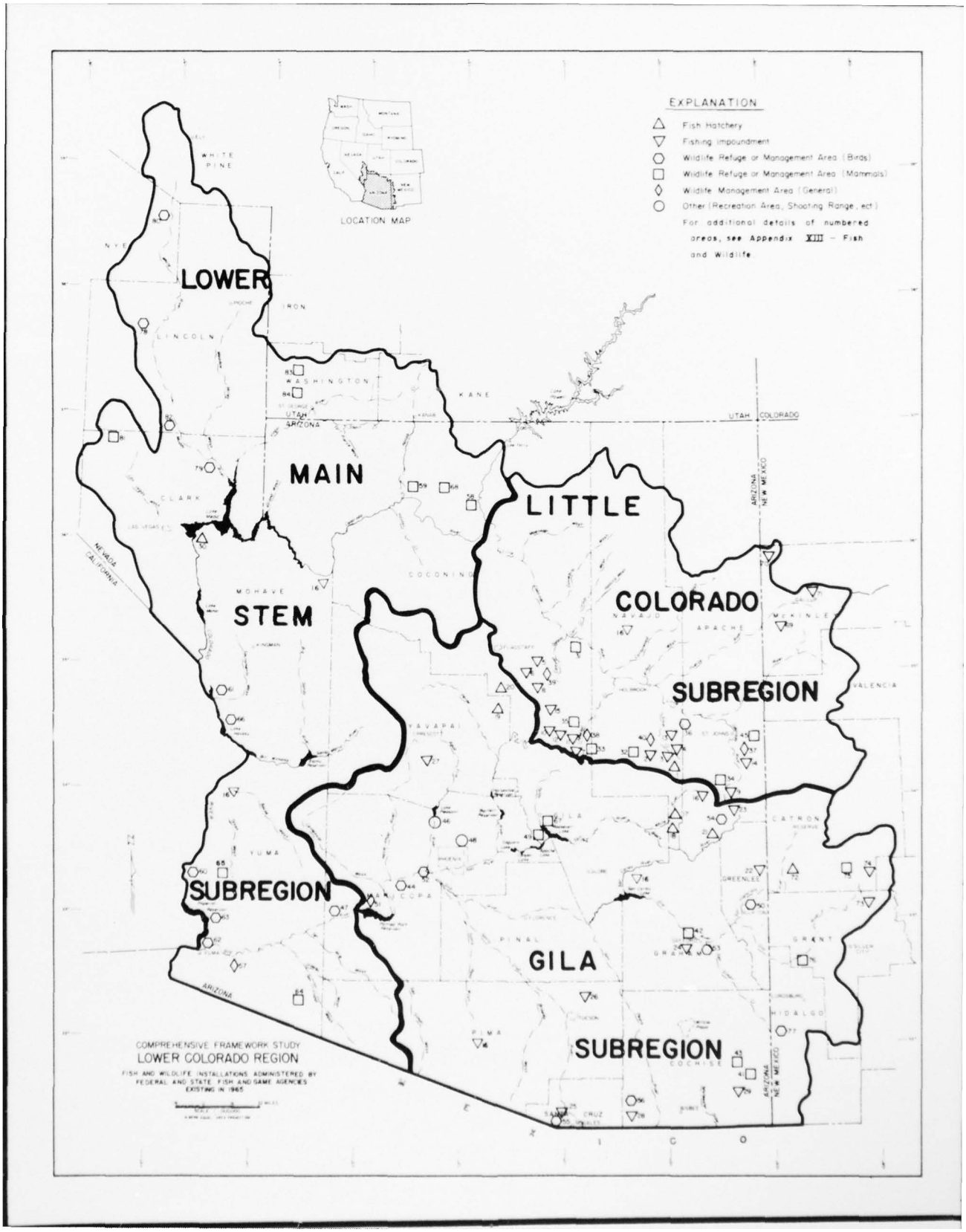
Though land requirements for power plants in the Lower Colorado Region are insignificant in amount, careful planning and site selection will be required to minimize environmental damages.

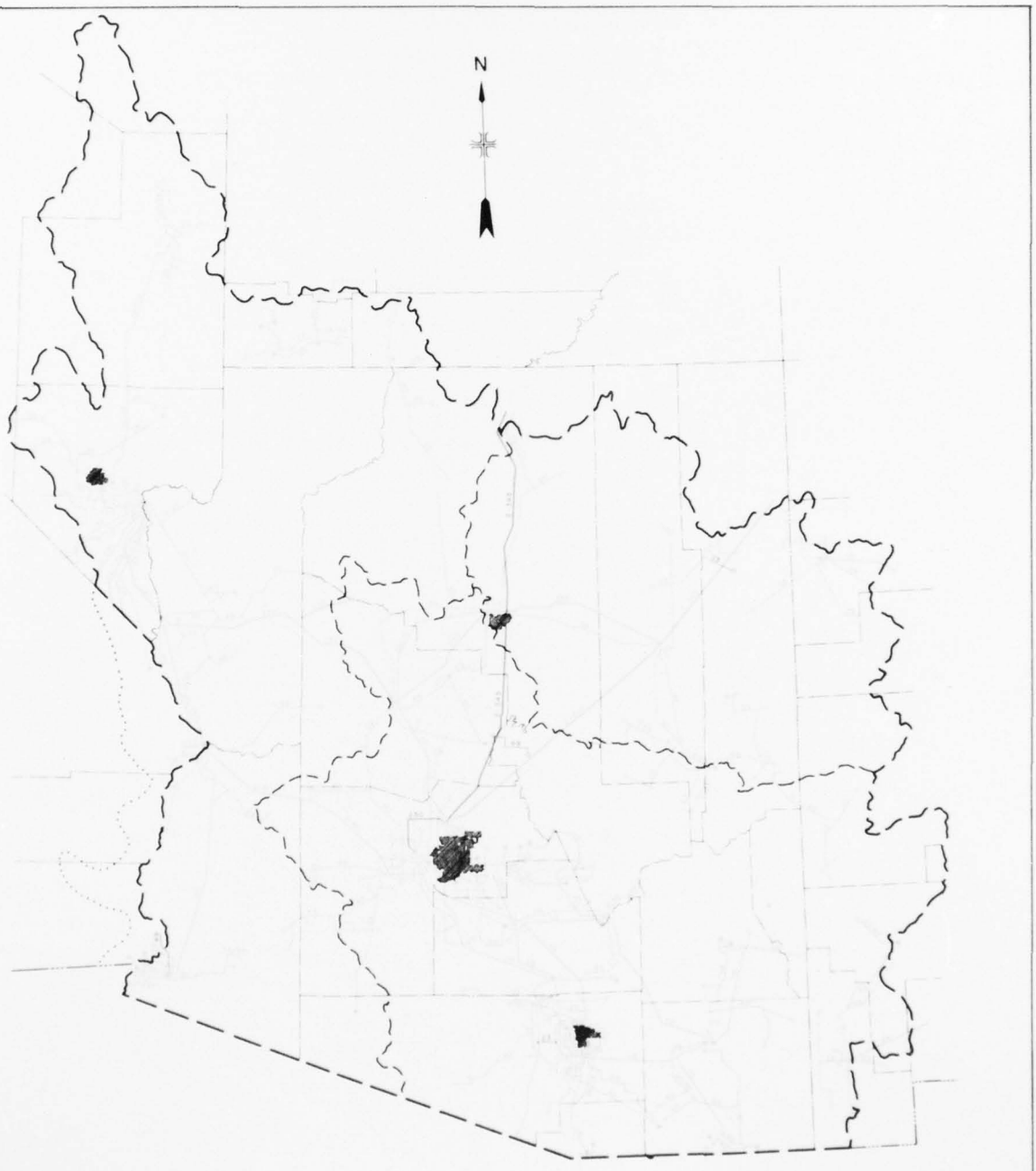
The annual amount of water consumed for electric power production in the Lower Colorado Region in 1965 was only about 10,000 acre-feet. Exact quantities of water storage required for power production are not available on a regional basis because virtually all of the water used by hydroelectric plants is stored for other primary purposes.

Through interconnection, power is exchanged with the California, Great Basin, and Upper Colorado Regions; a part of western New Mexico, Mexico, and the Federal Hydroelectric System of the Missouri River Basin. Principal electric facilities existing in 1965 are shown on the map following page 52.

The following graph depicts the classifications of consumers using electricity in 1965 in the Lower Colorado Region:




EXPLANATION
Fish Hatchery
Fishing Impoundment
Wildlife Refuge or Management Area (Birds)
Wildlife Refuge or Management Area (Mammals)
Wildlife Management Area (General)
Other (Recreation Area, Shooting Range, ect.)
For additional details of numbered areas, see Appendix XIII - Fish and Wildlife
LOCATION MAP
LOWER
MAIN
LITTLE
COLORADO
SUBREGION
STEM
SUBREGION
GILA
SUBREGION
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
FISH AND WILDLIFE INSTALLATIONS ADMINISTERED BY FEDERAL AND STATE FISH AND GAME AGENCIES EXISTING IN 1965
WHITE PINE
LINCOLN
IRON
WASHINGTON
KANE
UTAH
ARIZONA
COLORADO
CLARK
NEVADA
CALIFORNIA
MOHAVE
COCONINO
NAVAJO
APACHE
MCKINLEY
SAN JUAN
ARIZONA
NEW MEXICO
YAVAPAI
YUMA
MARICOPA
PINAL
GILA
GRAHAM
GREENLEE
GRANT
HIDALGO
PIMA
COCHISE
SANTA CRUZ
VALENCIA
CATRON
MEXICO



EXPLANATION

HYDRO POWER PLANT

FUEL POWER PLANT

SUBSTATION OR CITY

TRANSMISSION LINES

345 KV

230 - 287 KV

115 - 161 KV

69 KV

46 KV OR LESS

CONNECTING LINES

CROSS OVER LINES

UNDER CONSTRUCTION

NOTES:

1. TRANSMISSION LINES SIMPLIFIED IN CONGESTED AREAS.
2. POWER PLANTS UNDER 1,000 KW ARE NORMALLY NOT SHOWN.

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION

PRINCIPAL ELECTRIC FACILITIES JUNE 30, 1965

SCALE IN MILES

20 0 20 40 60 80

RESOURCES AVAILABILITY

CHAPTER E - WATER AND RELATED LAND RESOURCES AVAILABILITY

WATER

Surface Water

Colorado River

Flows originating in the Upper Colorado Region and released through Glen Canyon Dam, some 17 miles upstream from the Lower Colorado Region's hydrologic boundary at Lee Ferry, constitute a major source of water supply to the Region. Portions of the flow released from Glen Canyon Dam, together with tributary inflow in the Lower Colorado Region, are consumed by native vegetation, lost by evaporation from water surfaces, and are delivered to Mexico pursuant to treaty. The remaining portion of the flow is then available for use within the Lower Basin States of Arizona, Nevada, and California.

The Supreme Court decreed that, of the first 7.5 million acre-feet of Colorado River water annually available for use within the States, Arizona, Nevada, and California are apportioned 2.8 million acre-feet, 0.3 million acre-feet, and 4.4 million acre-feet, respectively. The Mexican Treaty of 1944 provides for delivery of 1.5 million acre-feet of water annually to Mexico. The Colorado River Compact provides, among other things, that the river at Lee Ferry will not be depleted below an aggregate of 75 million acre-feet for any period of 10 consecutive water years, and for the sharing between the Upper and Lower Basins of any burden which might arise because of the water treaty with Mexico.

The average annual undepleted flow of the Colorado River as it enters the Lower Colorado Region is estimated at about 15.09 million acre-feet for the 60-year period 1906 to 1965. In its undepleted state, with the contribution of the Gila River near the Mexican border, the Colorado River's average annual flow into Mexico would be about 15.9 million acre-feet. The annual virgin undepleted flow of the Colorado River at Lee Ferry, Arizona, and the progressive 10-year average are shown on Figure 8.

Local Runoff

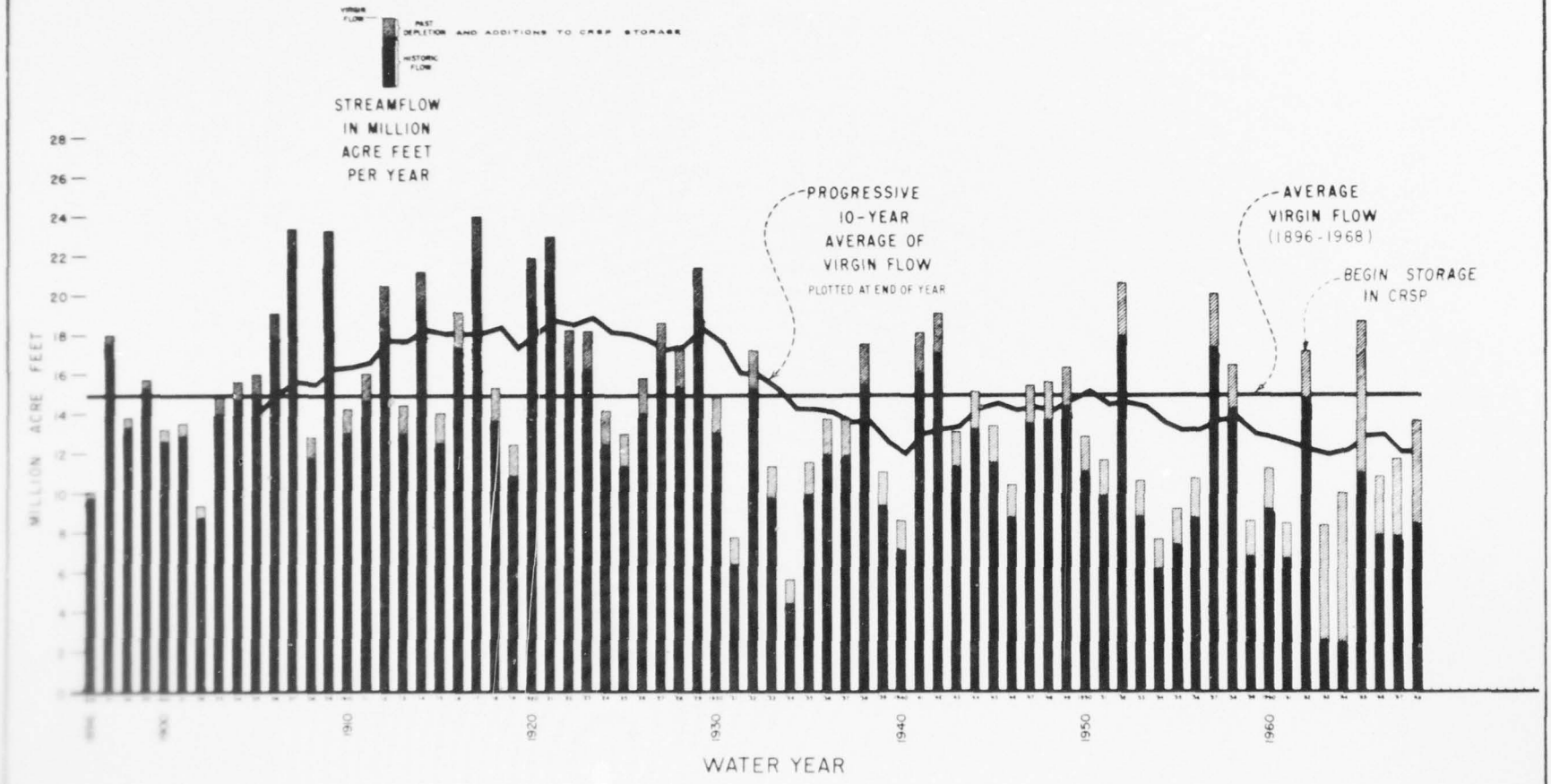
Approximately 100 million acre-feet of precipitation fall each year upon the Region, of which approximately 3 million acre-feet reach the streams or ground-water reservoirs for downstream use. The distribution, by subregion, of average annual runoff (undepleted flow)

FIGURE 8

VIRGIN FLOW
COLORADO RIVER AT COMPACT POINT
LEE FERRY

AVERAGE VIRGIN FLOW

PERIOD	MAF
1896-1968	14.82
1906-1965	15.09
1914-1965	14.64
1922-1965	13.87
1931-1965	13.09



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LOWER COLORADO REGION COMPREHENSIVE FRAMEWORK STUDY. MAIN REPOR--ETC(U)
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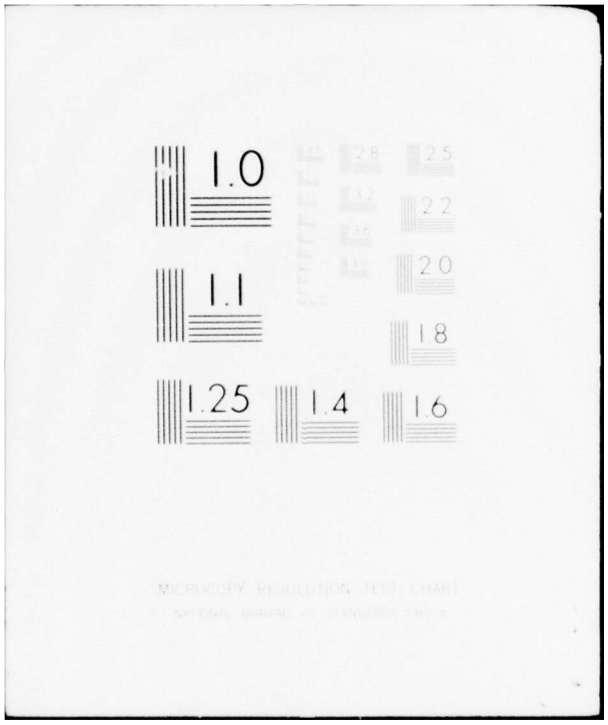

1.0
1.1
1.25
1.4
1.6
2.8
2.5
2.2
2.0
1.8
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

exclusive of Colorado River flow, for the period 1914 to 1965 is estimated as follows:

	Millions of Acre-Feet
Subregion 1 (Lower Main Stem)	0.90
Subregion 2 (Little Colorado)	0.42
Subregion 3 (Gila)	1.80
Total Lower Colorado Region	3.12

Present Modified Water Supply

To illustrate the sufficiency of regional water supply in 1965, an overall regional water balance was estimated by computing the remaining water supply in each subregion after all manmade depletions, evaporative losses, channel losses, system spills, and out-of-region diversions were subtracted.

Figure 9 illustrates that from a broad regional point of view, the total 1965 water supply in the Region was nearly equal in amount to the total water requirements. The apparent water supply deficiencies in the Gila Subregion could have been almost satisfied, assuming the hypothetical possibility of complete control and adequate facilities for redistribution of water from areas of surplus. It should be noted that for this condition to occur would require 100 percent utilization of regional runoff and 100 percent efficiency of water storage and transport facilities.

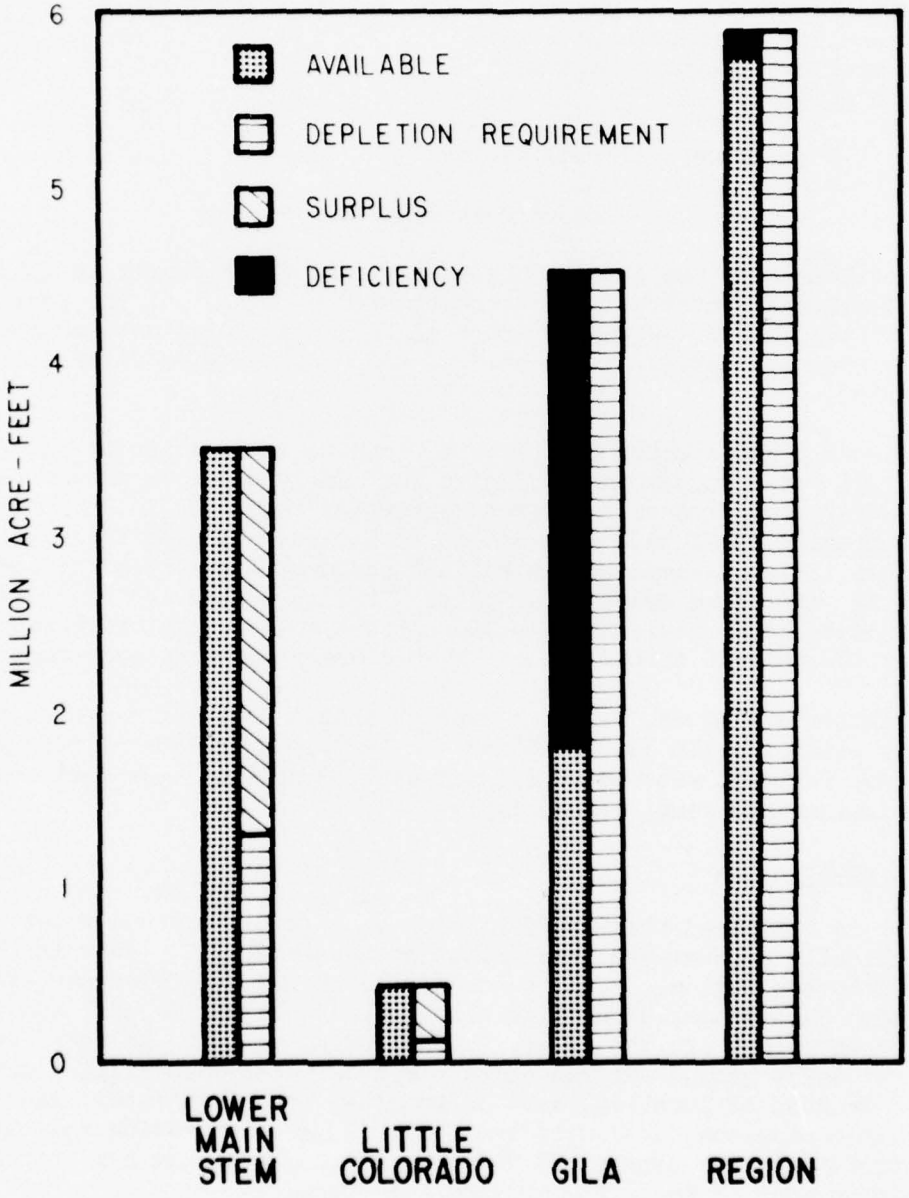
Similar estimates, based on average annual depleted flows at the compact point for the 1914-1965 and the 1922-1965 periods of record, show 1965 regional water deficiencies of 0.63 million acre-feet and 1.40 million acre-feet, respectively.

Ground Water

It is estimated that 1,430 million acre-feet of ground water are theoretically recoverable from depths of less than 1,200 feet in the Lower Colorado Region. Of this amount, about 1,150 million acre-feet are found in Arizona, 93 million acre-feet are in New Mexico, and 190 million acre-feet are in Nevada. The alluvial aquifers in the first 700 feet below ground surface contain approximately 990 million acre-feet. Because of location, cost of pumping, low yield rates, land subsidence problems, declining water levels, and increasing salinity of water at greater depths, it would be neither feasible nor practical to develop much of the 1,430 million acre-feet.

Efficient mining of these waters, as well as much of the ground water located nearer to the land surface, would require detailed well design, spacing, and installation of much deeper wells than currently

FIGURE 9
REGIONAL WATER BALANCE
1965



Land subsidence and fissures threaten a housing development in an area of heavy ground-water pumpage.

Area of high water yield, mixed conifer, White Mountains.

exist in most areas. These ground-water reserves can continue to serve future generations if they are properly managed and integrated with other sources of water made available to the Region. Long range water resource planning concepts should be established that would conserve and regulate this diminishing resource at a socially optimum level, particularly in growing metropolitan areas where heavy water demands will be sustained over long periods of time. The following maps show depths to ground water in 1965 and the 1960 to 1965 changes in depth to water.

Increased Water Yield

Increases in water yield can be obtained from forest land by reducing the water used by onsite vegetation. This increase can be realized by specific timber harvesting practices and by conversion of chaparral and deep-rooted riparian trees and shrubs to shallow-rooted grasses and forbs. The Water Yield Augmentation Map, following page 62, shows the extent of the areas suitable for this type of management.

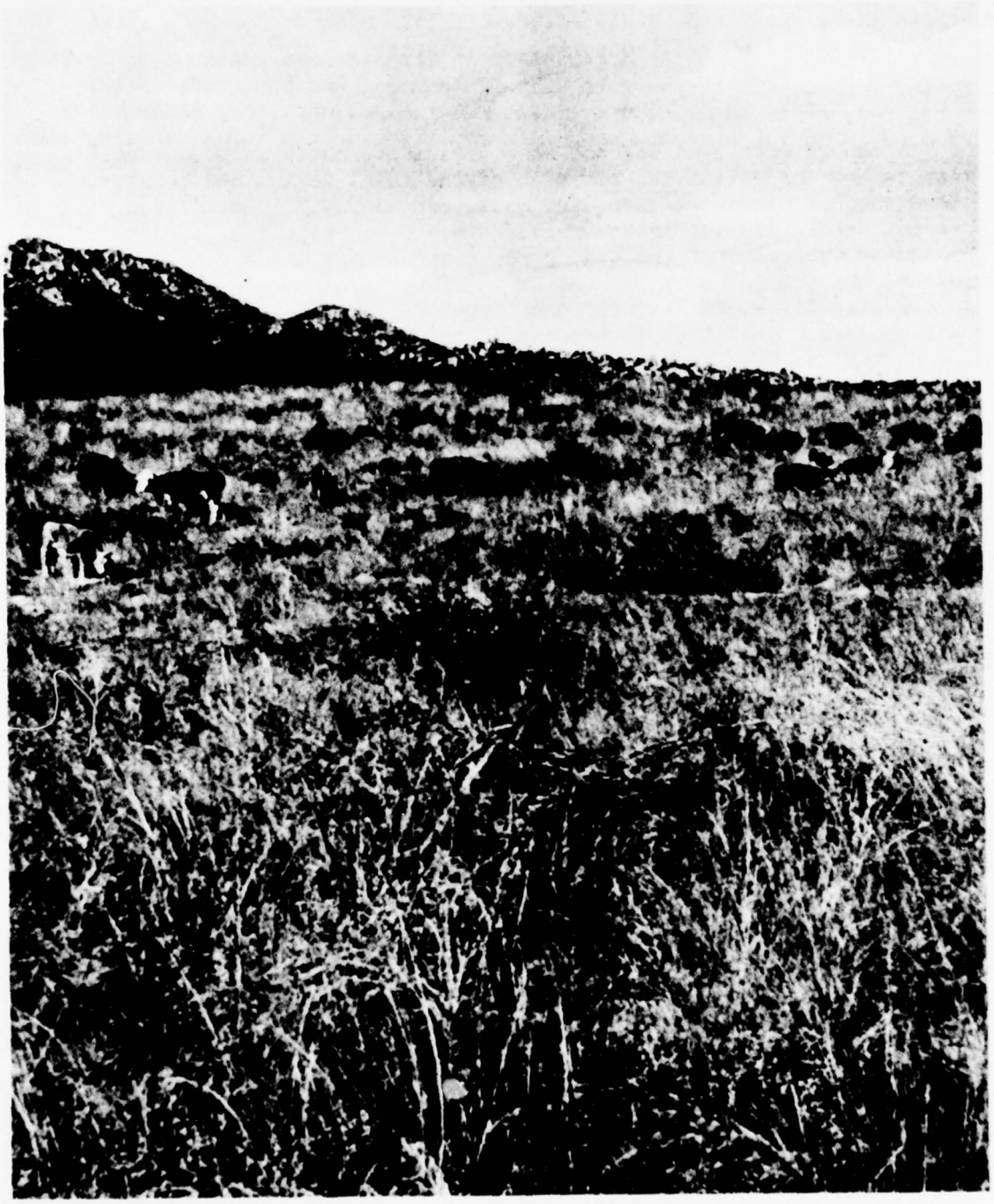
The maximum average annual potential increase in water yield within the Region through vegetation management is estimated at 1.1 million acre-feet from 5.1 million suitable acres. The amounts actually realized would be much less than this potential because of such considerations as esthetics, outdoor recreation, and wildlife habitat requirements and other land management objectives.

LANDS

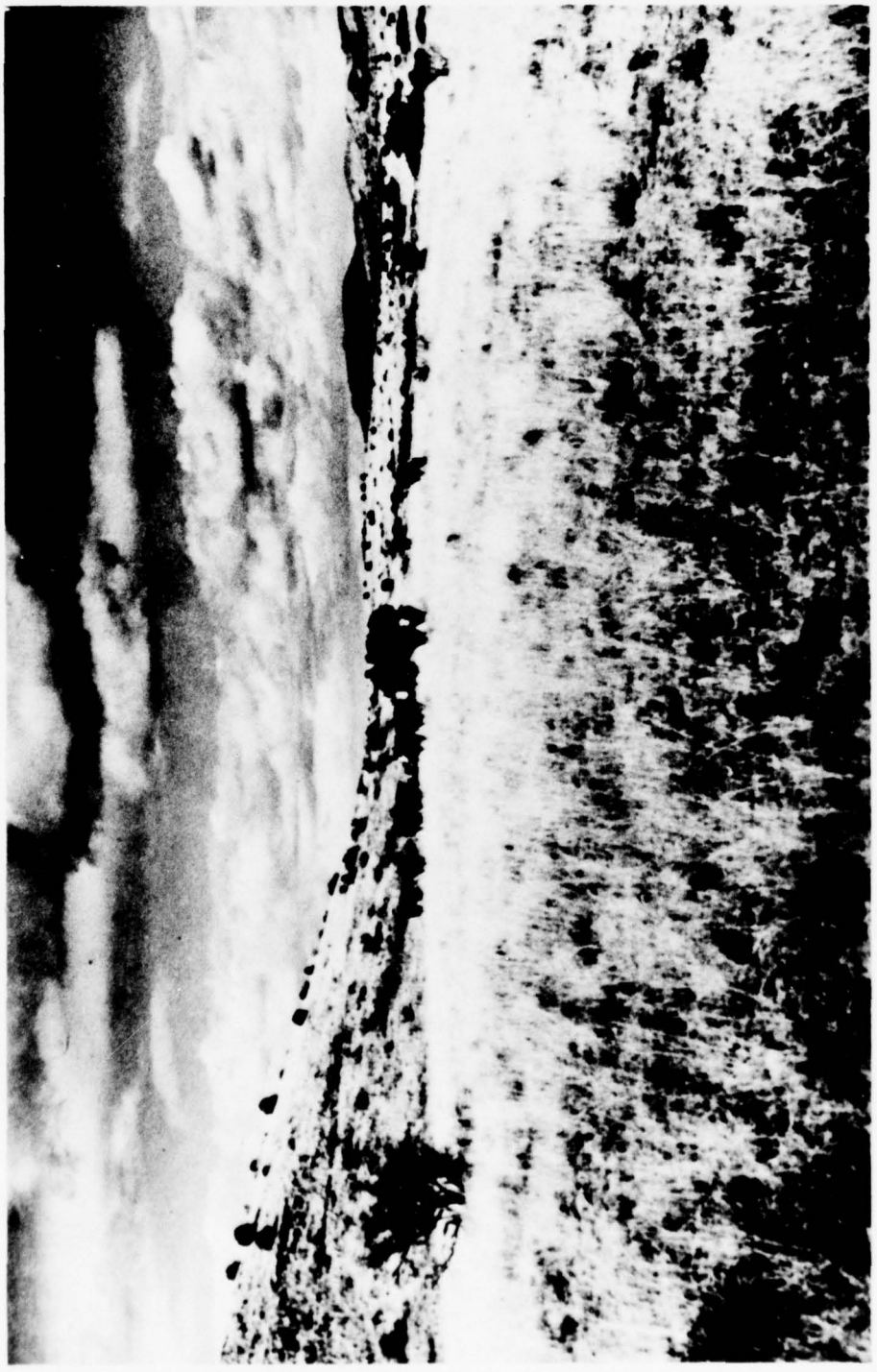
In 1965, there were approximately 36.2 million acres of land suitable for irrigated cropland in the Region. Of this acreage, about 1.6 million acres were also suitable for nonirrigated crop production. The availability of suitable lands will greatly exceed projected requirements for irrigated croplands and would also be far in excess of that which could be irrigated with projected water supply developments.

In 1965, there were approximately 85 million acres of land suitable for livestock grazing in the Region, of which about 76 million acres were available. This included 25 million acres of forest types (conifer, woodland, chaparral, and riparian), 51 million acres of range types (southern and northern desert shrub and grassland), all croplands, and portions of undeveloped lands within urban areas.

Of the 30 million acres of forest land in the Lower Colorado Region, 6 million acres are suitable for the production of commercial timber products. About one-half million acres of this land are included within the boundaries of national parks and other areas where commercial timber harvesting is modified or precluded.

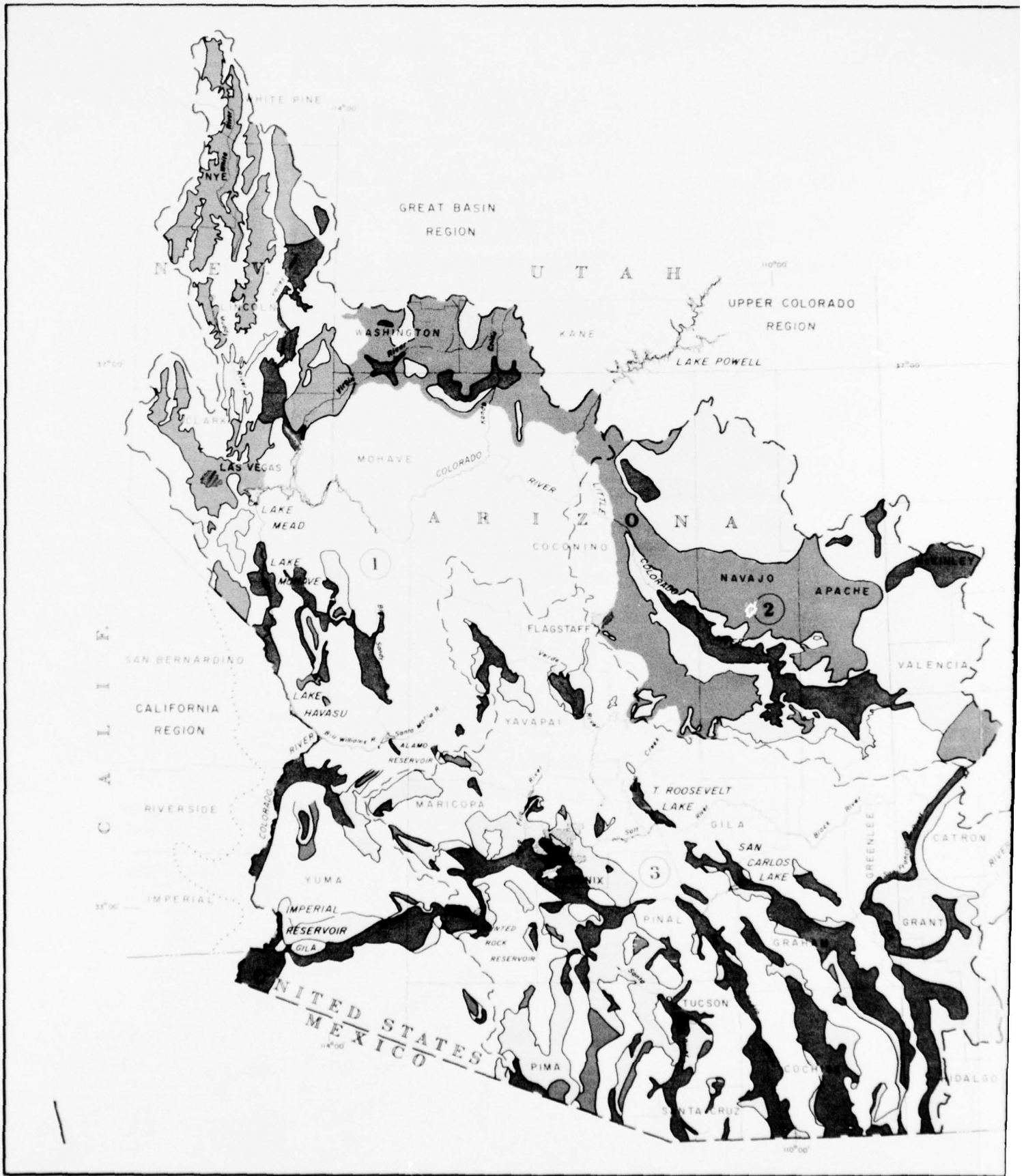


Area converted from chaparral to grass for water yield and improved forage.



Suitable grazing lands

Typical commercial timberland.


GREAT BASIN
REGION
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NEVADA
UTAH
ARIZONA
NYE
WHITE PINE
WASHINGTON
KANE
LAKE POWELL
LAS VEGAS
MOHAVE
COLORADO RIVER
LITTLE COLORADO
LAKE MEAD
LAKE MOHAVE
COCONINO
NAVAJO
APACHE
MCKINLEY
FLAGSTAFF
VALENCIA
SAN BERNARDINO
LAKE HAVASU
YAVAPAI
ALAMO RESERVOIR
RIVERSIDE
MARICOPA
T ROOSEVELT LAKE
GILA
SAN CARLOS LAKE
GREENLEE
GRAHAM
GRANT
YUMA
IMPERIAL
IMPERIAL RESERVOIR
PINAL
TUCSON
PIMA
SANTA CRUZ
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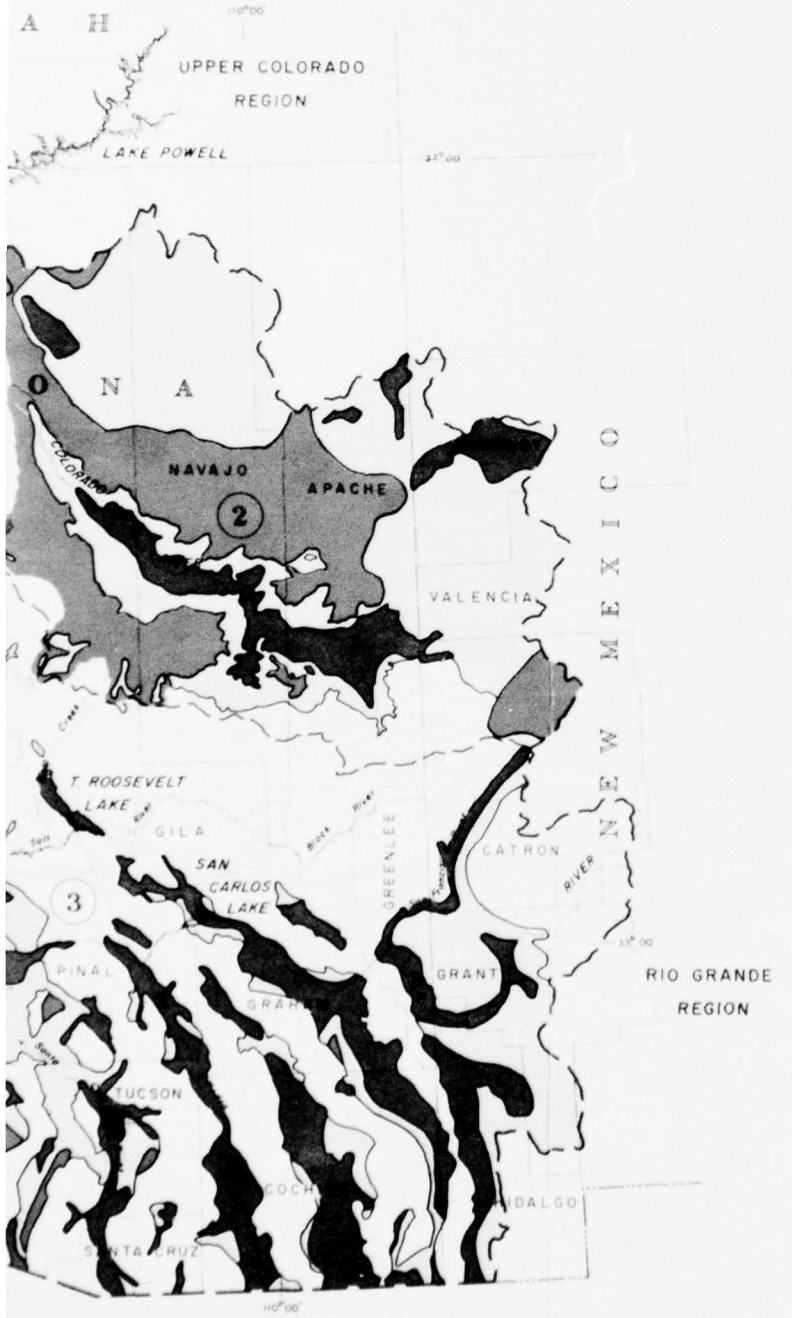


EXPLANATION

- Lower Colorado Region boundary
- Subregion boundary
- 1 Lower Main Stem
- 2 Little Colorado
- 3 Gila
- Lower Colorado Basin boundary
- Existing dam and reservoir
- Existing dam and intermittent lake
- Mountainous or insufficient data to delineate.
- Less than 200 feet
- From 200 to 500 feet
- Greater then 500 feet
- From 0 to 500 feet

COMPREHENSIVE FRAMEWORK STUDY

LOWER COLORADO REGION-HYDROLOGIC

DEPTH TO WATER

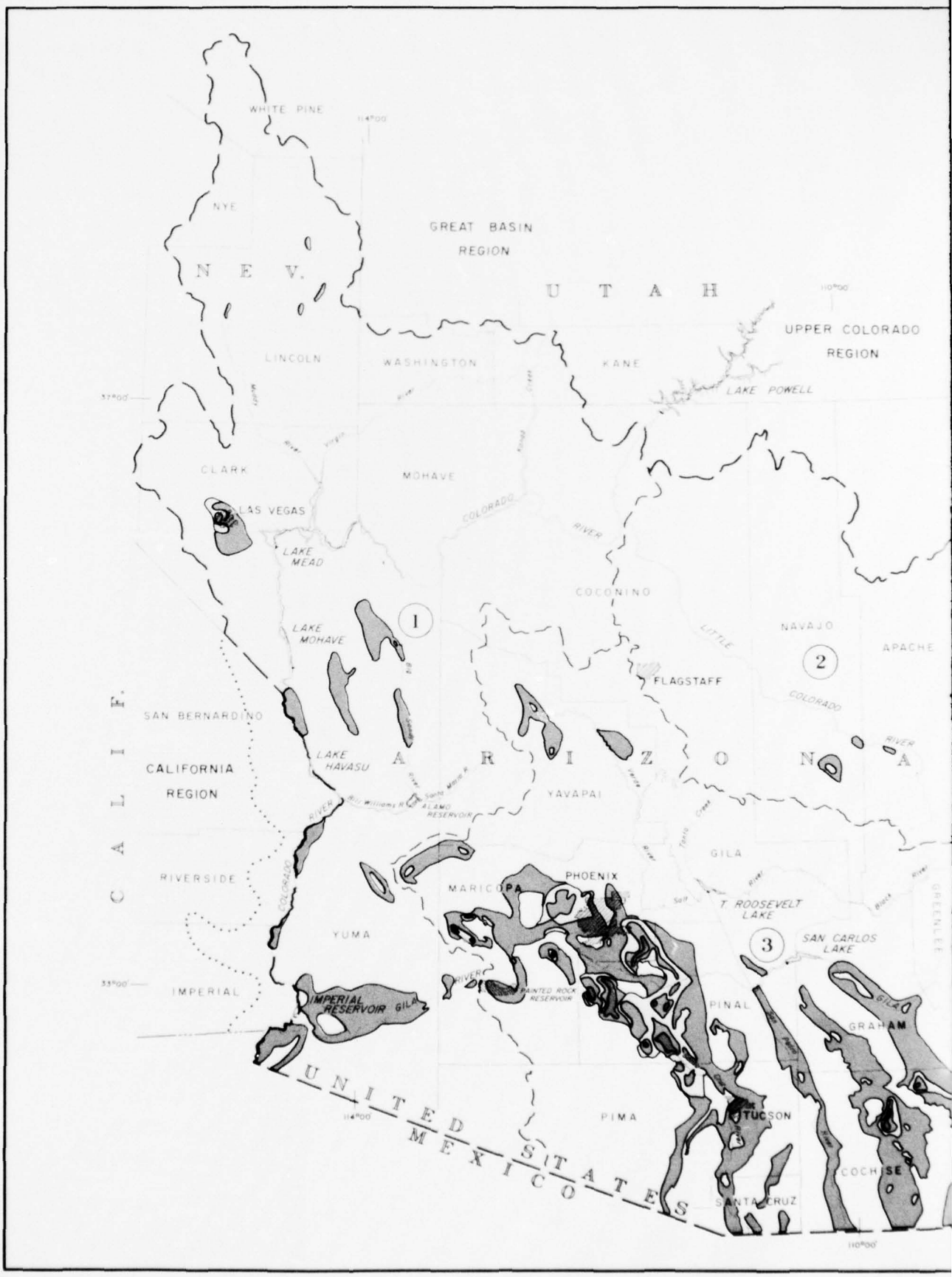
1965

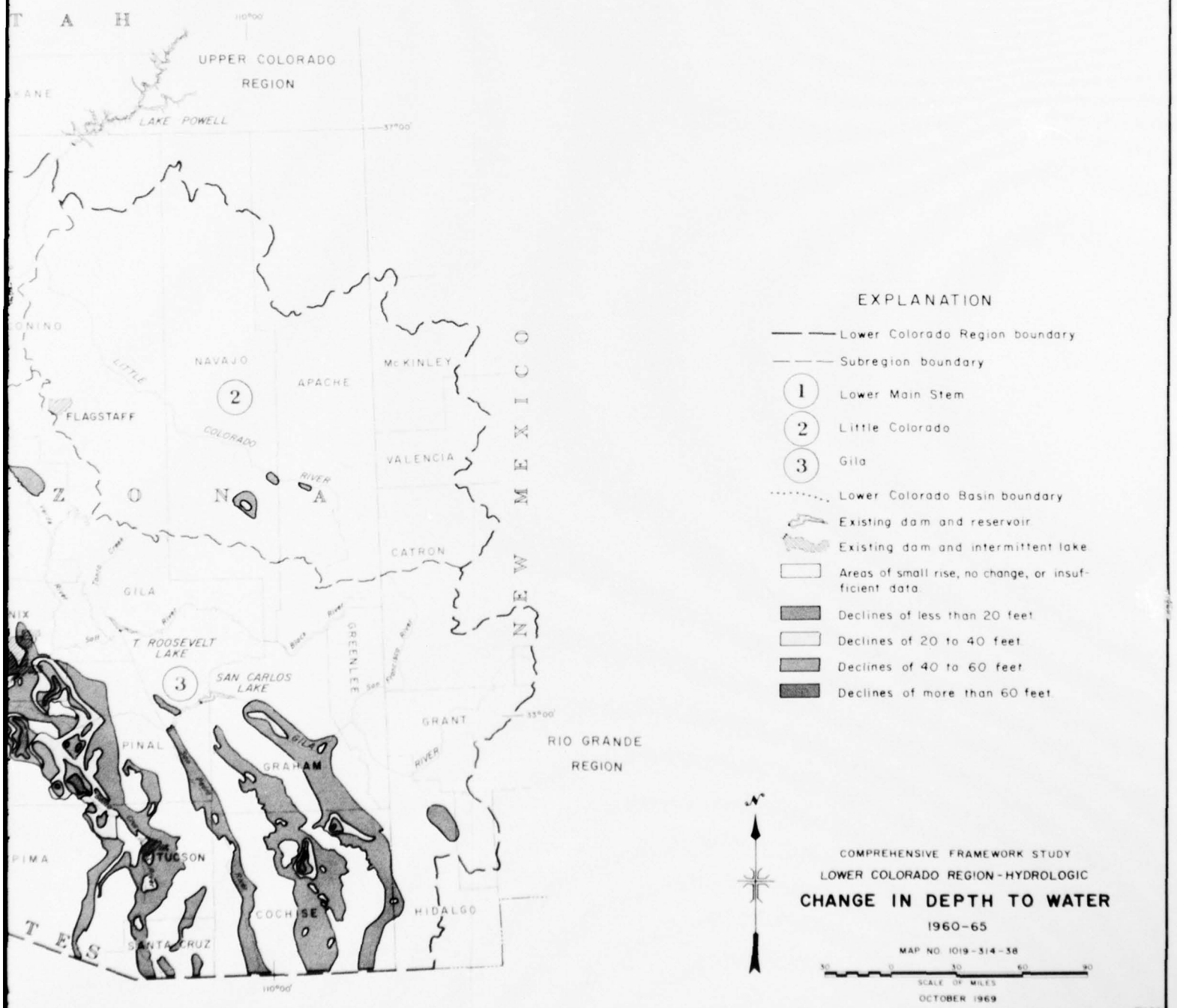
MAP NO. 1019-314-37

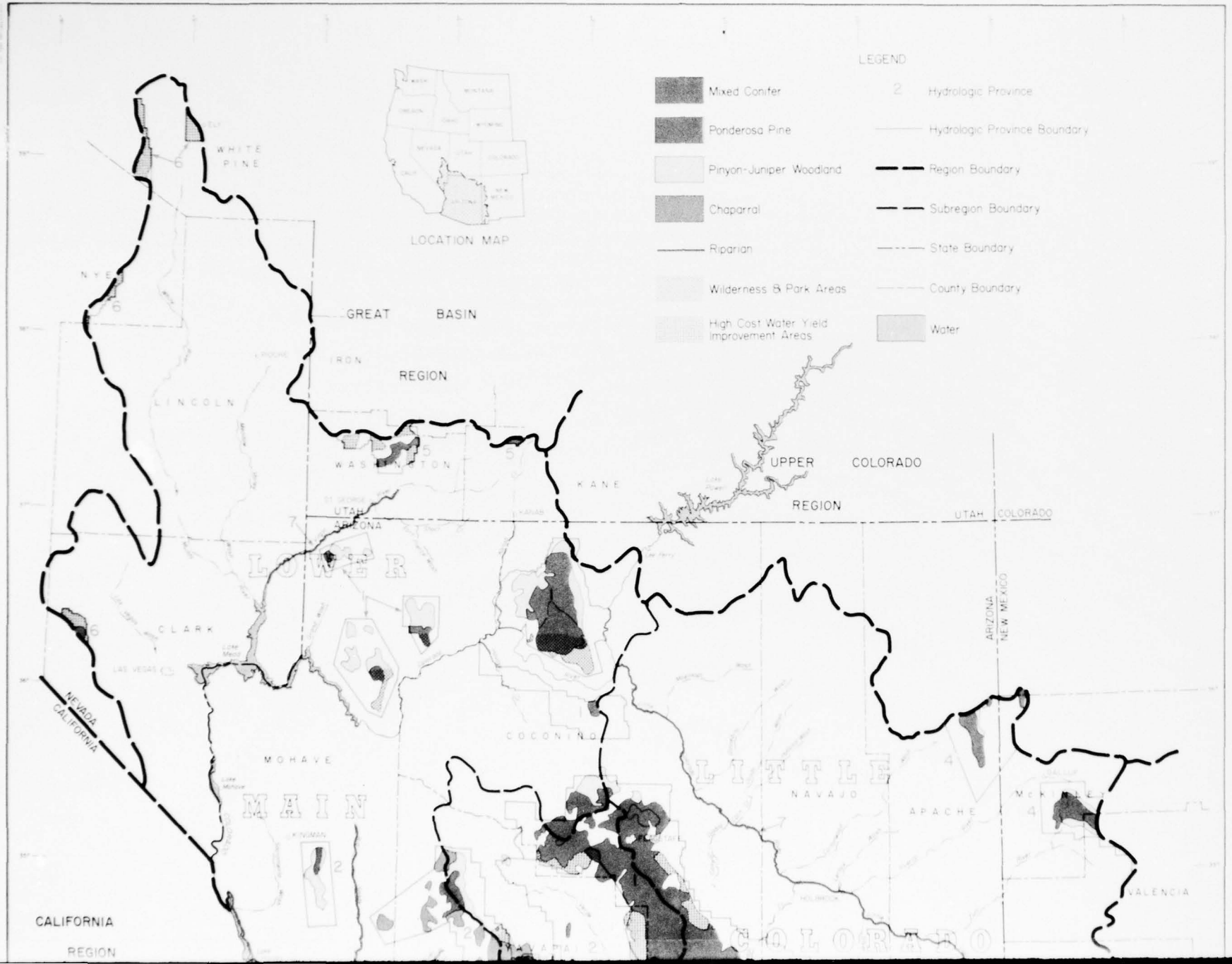
30 0 30 60 90

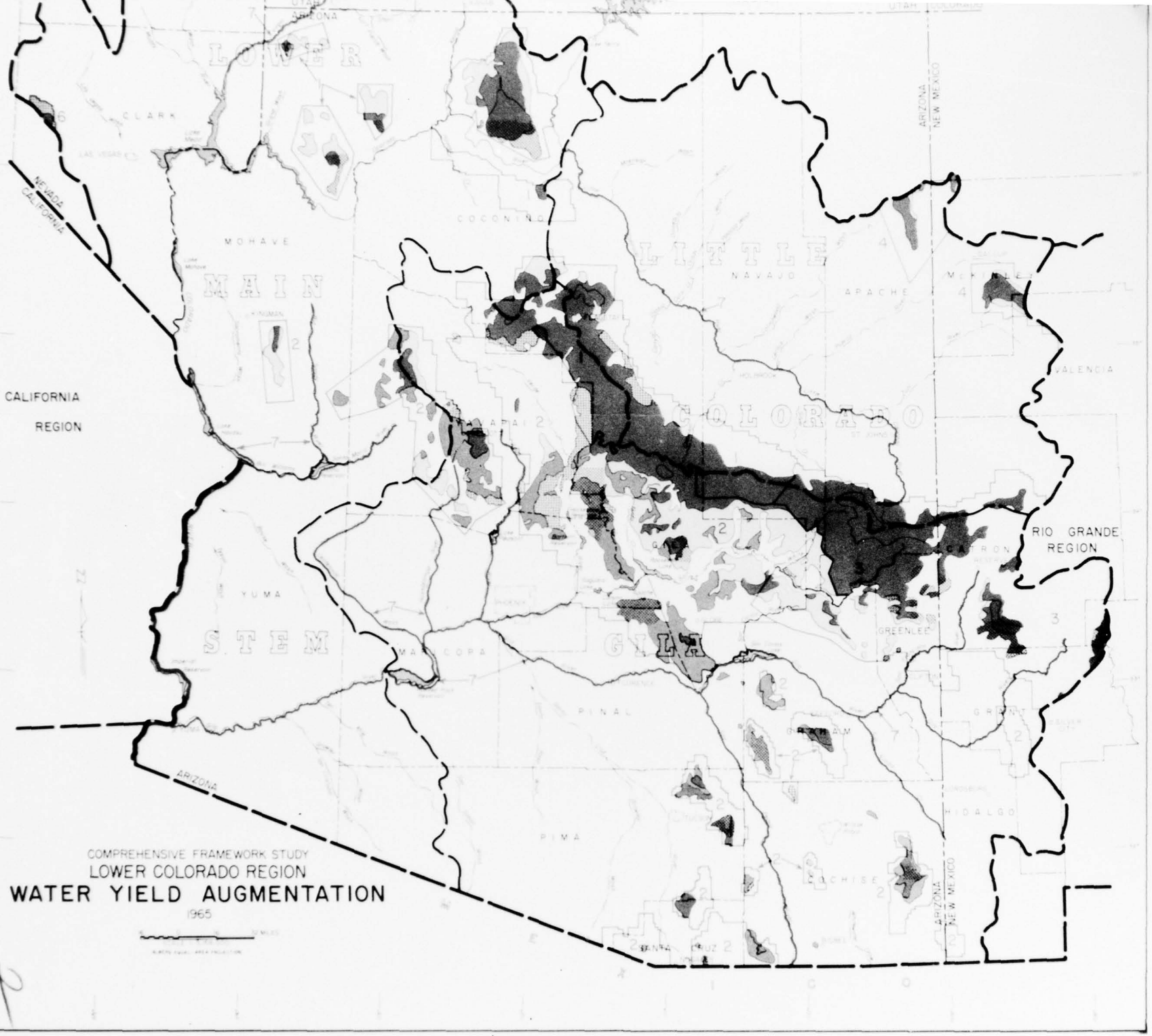
SCALE OF MILES

OCTOBER 1969


WHITE PINE
NYE
GREAT BASIN
REGION
N E V.
U T A H
UPPER COLORADO
REGION
LINCOLN
WASHINGTON
KANE
LAKE POWELL
CLARK
MOHAVE
LAS VEGAS
LAKE
MEAD
COLORADO
RIVER
COCONINO
LAKE
MOHAVE
1
NAVAJO
APACHE
2
FLAGSTAFF
SAN BERNARDINO
CALIFORNIA
REGION
LAKE
HAVASU
A R I Z O N A
YAVAPAI
ALAMO
RESERVOIR
GILA
RIVERSIDE
PHOENIX
MARICOPA
T. ROOSEVELT
LAKE
YUMA
3
SAN CARLOS
LAKE
IMPERIAL
PAINTED ROCK
RESERVOIR
IMPERIAL
RESERVOIR
GILA
PINAL
GRAHAM
U N I T E D S T A T E S
PIMA
TUCSON
COCHISE
SANTA CRUZ
M E X I C O


UPPER COLORADO
REGION
LAKE POWELL
NAVAJO
APACHE
McKINLEY
FLAGSTAFF
VALENCIA
CATRON
GILA
T ROOSEVELT
LAKE
SAN CARLOS
LAKE
GRANT
PINAL
GRAHAM
RIO GRANDE
REGION
TUCSON
COCHISE
HIDALGO
SANTA CRUZ
EXPLANATION
Lower Colorado Region boundary
Subregion boundary
1 Lower Main Stem
2 Little Colorado
3 Gila
Lower Colorado Basin boundary
Existing dam and reservoir
Existing dam and intermittent lake
Areas of small rise, no change, or insufficient data
Declines of less than 20 feet
Declines of 20 to 40 feet
Declines of 40 to 60 feet
Declines of more than 60 feet
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION - HYDROLOGIC
CHANGE IN DEPTH TO WATER
1960-65
MAP NO. 1019-314-38
SCALE OF MILES
OCTOBER 1969


LEGEND
Mixed Conifer
Ponderosa Pine
Pinyon-Juniper Woodland
Chaparral
Riparian
Wilderness & Park Areas
High Cost Water Yield Improvement Areas
2 Hydrologic Province
Hydrologic Province Boundary
Region Boundary
Subregion Boundary
State Boundary
County Boundary
Water
LOCATION MAP
GREAT BASIN REGION
UPPER COLORADO REGION
LOWER MAIN
CALIFORNIA REGION
WHITE PINE
LINCOLN
CLARK
IRON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
MCKINLEY
VALENCIA
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
CALIFORNIA


CALIFORNIA
REGION
RIO GRANDE
REGION
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
ARIZONA
NEW MEXICO
ARIZONA
LOWER
MAIN
STEM
LITTLE
COLORADO
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NAVAJO
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YUMA
MARICOPA
PINAL
GREENLEE
GRAHAM
GILA
PIMA
COCHISE
SANTA CRUZ
HIDALGO
VALENCIA
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
WATER YIELD AUGMENTATION
1965


VICINITY MAP
OREGON
IDAHO
WYOMING
NEVADA
UTAH
COLORADO
CALIFORNIA
Lower
ARIZONA
NEW MEXICO
Colorado
GREAT
BASIN
REGION
UPPER
COLORADO
REGION
LOWER
COLORADO
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LITTLE
COLORADO
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WHITE PINE
NYE
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MCKINLEY
YAVAPAI
GILA
GREENLEE
GRAHAM
GRANT
YUMA
MARICOPA
PINAL
PIMA
COCHISE
HIDALGO
SANTA CRUZ
M E X I C O
SONORA
CHIHUAHUA
LEGEND
REGION BOUNDARY
SUBREGION BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
COLORADO RIVER DRAINAGE
POTENTIAL WILD, SCENIC, & RECREATION RIVERS
SEE BACK OF MAP FOR DESCRIPTION
WILD, SCENIC, AND RECREATION
RIVER POTENTIAL
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
SCALE
MILES

I	Colorado River - Glen Canyon Dam to Lake Mead
II	North Fork Diamond Creek
III	Little Colorado River - Grand Falls to confluence with Colorado River
IV	Oak Creek - source to confluence with Verde River
V	Chevelon Creek
VI	Verde River - headwaters of Horseshoe Lake to confluence with West Clear Creek
VII	East Verde River
VIII	Tonto Creek
IX	White River
X	Salt River - source to Stewart Mountain Dam
XI	Black River
XII	Gila River - source to Florence
XIII	Colorado River - Davis Dam to International Boundary (particularly Topock Gorge and Imperial Division)

Most lands are suitable for outdoor recreation. Most public lands and a substantial amount of private land holdings are available for this purpose. Indian trust lands, considered as private, have very good potential for outdoor recreation development within the Region. Several rivers of the Region are considered to have potential for designation as wild, scenic, and recreation rivers. In addition to the nearly 1.5 million acres of existing designated wilderness areas, there are some 1.7 million acres that have been suggested for potential wilderness areas. It is anticipated there will be substantial blocks of suitable land available for designation as wilderness areas. Through appropriate action by state and Federal legislative bodies, adequate lands could be made available for the recommended sites for preservation of archeological, cultural, and historic values. Areas suitable for designation as wild, scenic, and recreation rivers are shown on the map "Wild, Scenic, and Recreation River Potential" which follows page 62.

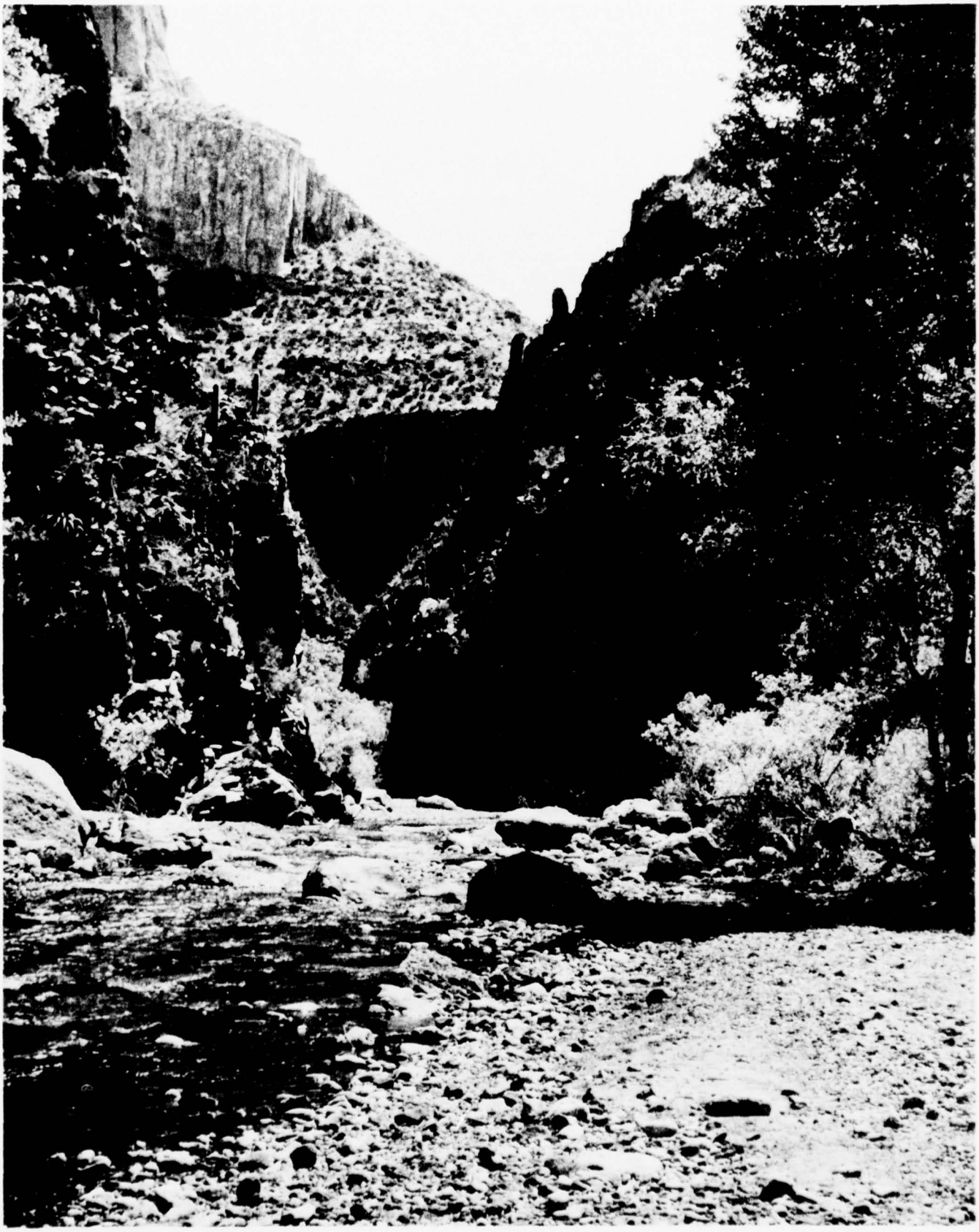
Most of the Region provides habitat and is of value to both game and nongame species of fish and wildlife, although much of the habitat is not of high quality. It is estimated that 76.4 million acres of the Region contribute materially as important habitat for wildlife, and most are available for fishing and hunting. Generally, game and nongame species are compatible and commonly inhabit similar areas.

Large amounts of land are not required for mineral production and such lands will be available when demand for the resource makes new developments economically feasible.

The lands presently in military and related uses in the Region are largely on barren desert or semiarid mountainous terrain. This land was selected for military uses because it avoided conflict with other land development and provided the space and security for military operations. Additional lands of this type exist and could be made available if required.

MINERALS

Minerals customarily produced in the Lower Colorado Region in important quantities are assumed to exist in known and unknown mineral deposits in sufficient quantities to satisfy all reasonable demands. Those minerals produced for consumption almost exclusively within the Region--sand, gravel, stone, lime, and other construction materials--seemingly are present in inexhaustible quantities. Quantities of existing deposits of lead, zinc, and uranium cannot be fully defined; there is, however, a vast area in which geologic conditions appear favorable for future discoveries when economic incentives warrant the exploration effort. Copper, backbone of the regional minerals industry, has an exceptionally strong resource base. Access for exploration and development of both public and private mineral-bearing land has been assumed to



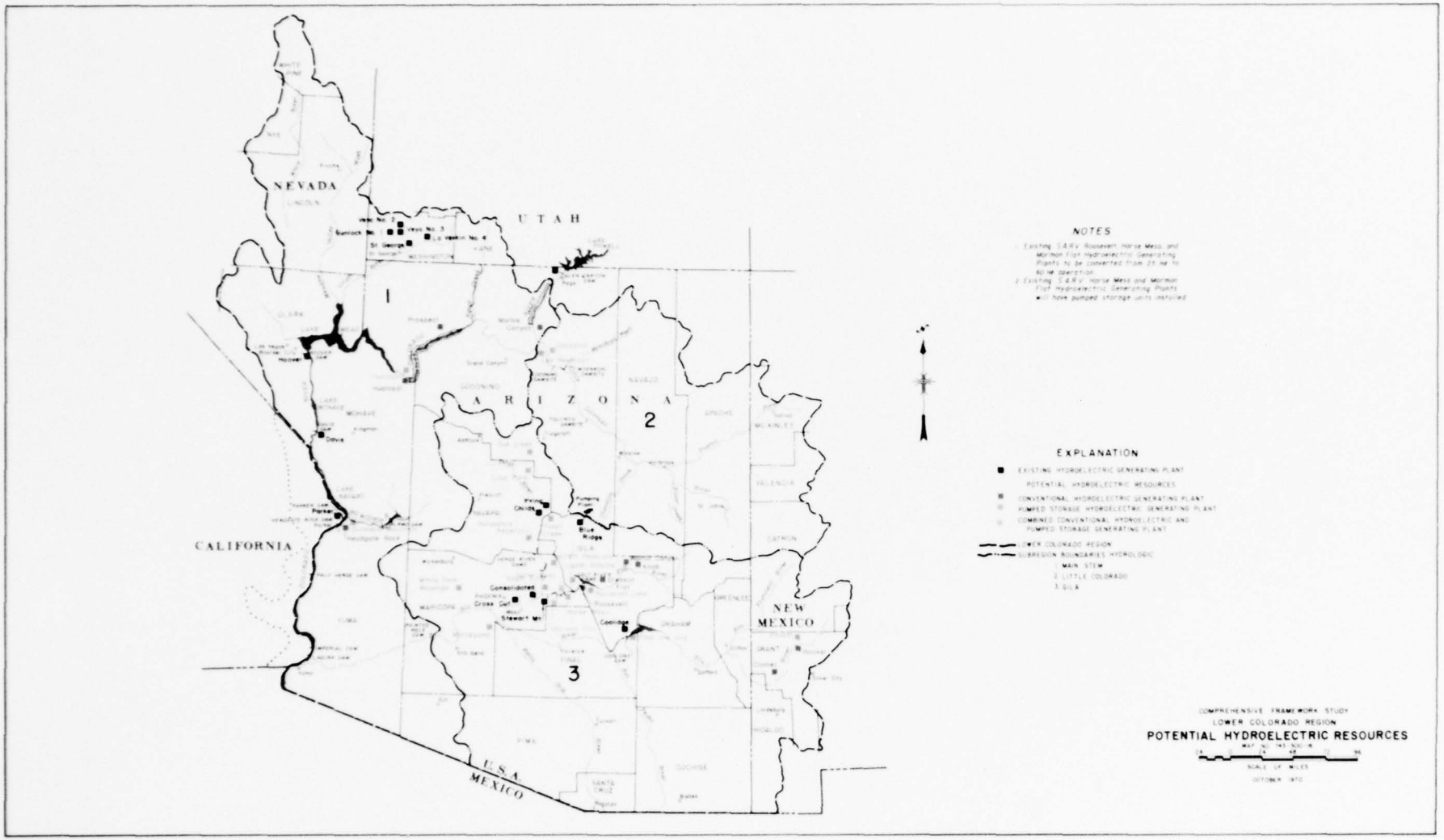
be readily available when subsequent mining operations are developed in an orderly manner with due consideration to environmental factors.

ELECTRIC POWER

There are a significant number of potential conventional and pumped storage hydroelectric power generation sites in the Region which have been studied in varying degrees. These sites on the mainstream of the Colorado River between Hoover and Glen Canyon Dams, though opposed by the conservationists, are still potential sites. The locations of these and other potential hydroelectric resources sites are shown on the following map, "Potential Hydroelectric Resources."

GEOTHERMAL RESOURCES

Although the Lower Colorado Region has several dozen springs classified as "thermal," none have exceptionally high temperatures. Very deep alluvial basins with high contents of thermal water sufficient to be of economic interest may possibly occur in the Region; however, if such do occur, they have not obvious surface expression and have remained undiscovered by drilling. In general, the geothermal potential of the Region is presently unknown.



NOTES

1. Existing S.A.R.V. Roosevelt, Horse Mesa, and Mormon Flat Hydroelectric Generating Plants to be converted from 25 HZ to 60 HZ operation.
2. Existing S.A.R.V. Horse Mesa and Mormon Flat Hydroelectric Generating Plants will have pumped storage units installed

EXPLANATION

- EXISTING HYDROELECTRIC GENERATING PLANT
- POTENTIAL HYDROELECTRIC RESOURCES
- CONVENTIONAL HYDROELECTRIC GENERATING PLANT
- PUMPED STORAGE HYDROELECTRIC GENERATING PLANT
- COMBINED CONVENTIONAL HYDROELECTRIC AND PUMPED STORAGE GENERATING PLANT
- LOWER COLORADO REGION
- SUBREGION BOUNDARIES HYDROLOGIC
  - MAIN STEM
  - 2 LITTLE COLORADO
  - 3 GILA

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

POTENTIAL HYDROELECTRIC RESOURCES

SCALE OF MILES

OCTOBER 1970

FUTURE REQUIREMENTS

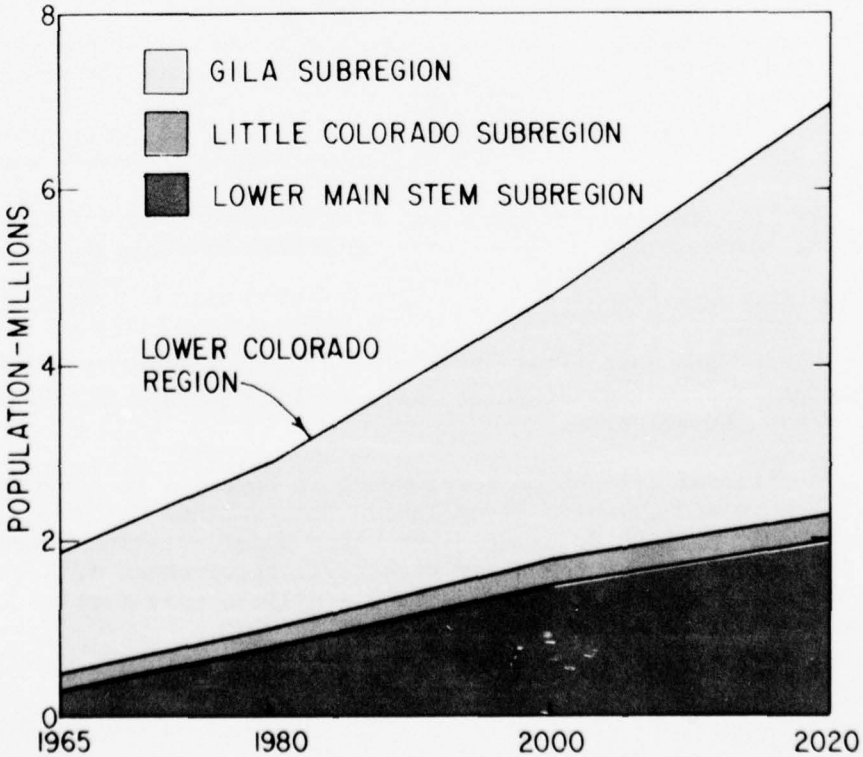
CHAPTER F - FUTURE REQUIREMENTS

INTRODUCTION

The Lower Colorado Region's growth in population and economy is dependent on solving the present water deficiency and providing for future needs. The Region is richly endowed with other natural resources needed to meet the demands of an increasing population. This chapter presents the projected water and related land requirements for the Region from 1965 through 2020.

The modified OBE-ERS projections, which are being used for the development of the Lower Colorado Region framework program, are based on the national OBE-ERS projections adjusted to reflect local conditions. Population growth is depicted by Figure 10.

FIGURE 10
POPULATION GROWTH
(ECONOMIC REGION)



Lower Colorado Region

By 1980, projections indicate a water deficiency of about 1.51 million acre-feet, increasing to more than 4.5 million acre-feet by 2020. Previous studies have indicated that the Colorado River flows would need to be augmented to fulfill present commitments of 3.1 million acre-feet to the Lower Colorado Region, 4.4 million acre-feet to California, and 1.5 million acre-feet to the Republic of Mexico.

Estimated 1965 and projected regional water withdrawal and depletion requirements are presented in Figures 11 and 12. It should be noted that quantities shown are estimated water requirements and not quantities actually withdrawn in 1965. Water withdrawals for all uses are expected to increase to a level of 12.96 million acre-feet by 2020. Projected increases are associated primarily with the needs resulting from population growth in the Region. Municipal and industrial water withdrawal requirements are expected to increase by 2.3 million acre-feet; for electric power generation, 0.425 million acre-feet; for mineral development, 0.252 million acre-feet; and for recreation, fish and wildlife, 0.4 million acre-feet. Irrigation withdrawal requirements would remain about the same level as for 1965. Water saved by increasing management efficiencies and lining of canals would satisfy increased requirements resulting from additional irrigation developments.

The most critical immediate need is to meet withdrawal requirements projected to occur prior to 1980 without increasing the ground-water overdraft. To gradually eliminate the ground-water overdraft, the long-range program, 1981 to 2020, would need to provide for increased annual water withdrawals of about 4.5 million acre-feet from new sources.

The present and projected water withdrawal and depletion requirements for the Lower Colorado Region are summarized in Table 5.

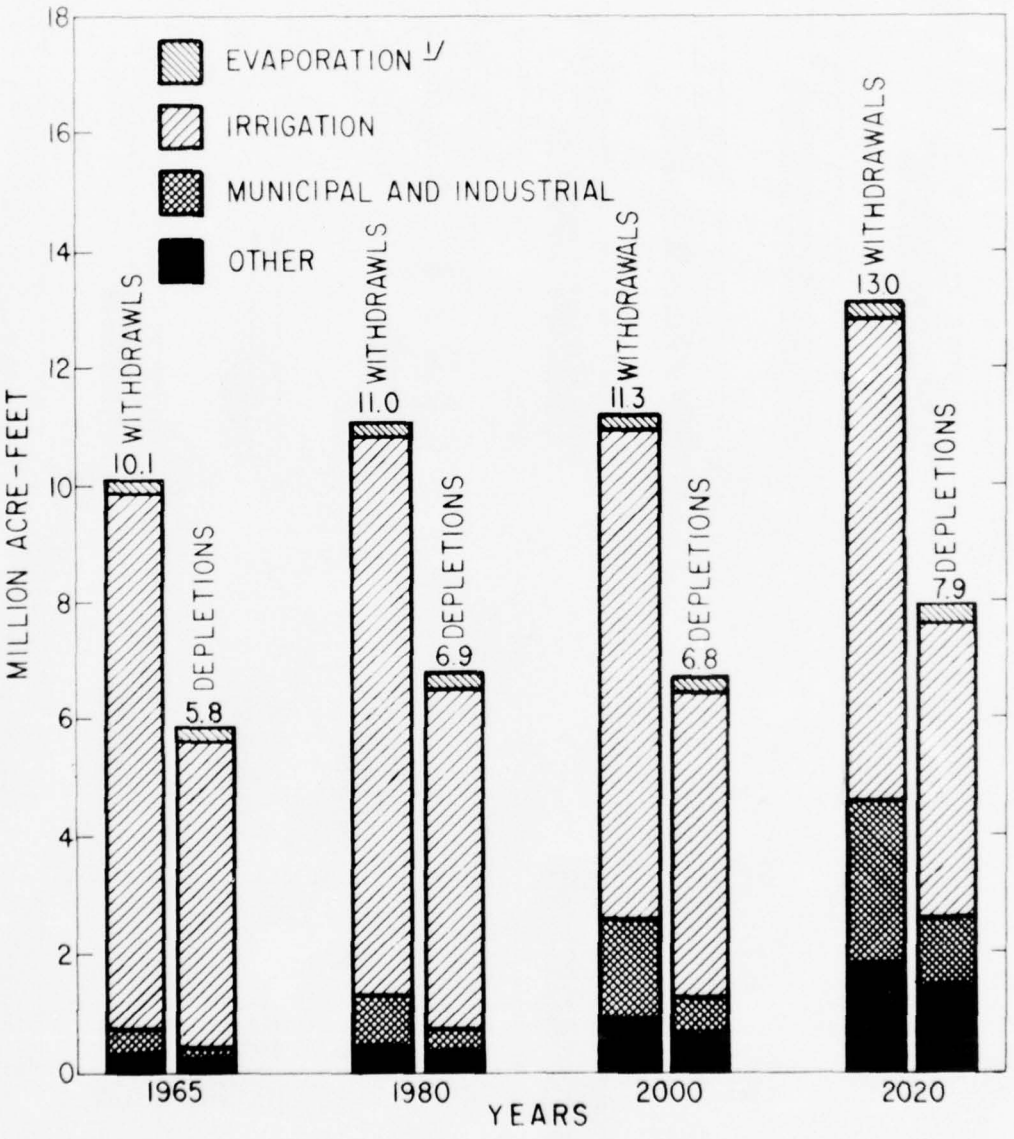
Lower Main Stem Subregion

One of the most vital needs of the Lower Main Stem Subregion is the municipal and industrial water for a rapidly growing population in the Las Vegas, Nevada area.

Additional irrigation development is expected to occur within the Fort Mohave and Colorado River Indian Reservations and other areas which would utilize Colorado River water under existing water rights. It is estimated that the water withdrawal requirement of 3.0 million acre-feet in 1965 will increase to 3.4 million acre-feet by 1980 and then increase to 3.8 million acre-feet by 2020.

FIGURE 11

PROJECTED REGIONAL WATER REQUIREMENTS



1/ Excluding Colorado River mainstem evaporation, losses estimated to be 1.2 million acre-feet annually.

FIGURE 12

PROJECTED REGIONAL WATER REQUIREMENTS BY USES

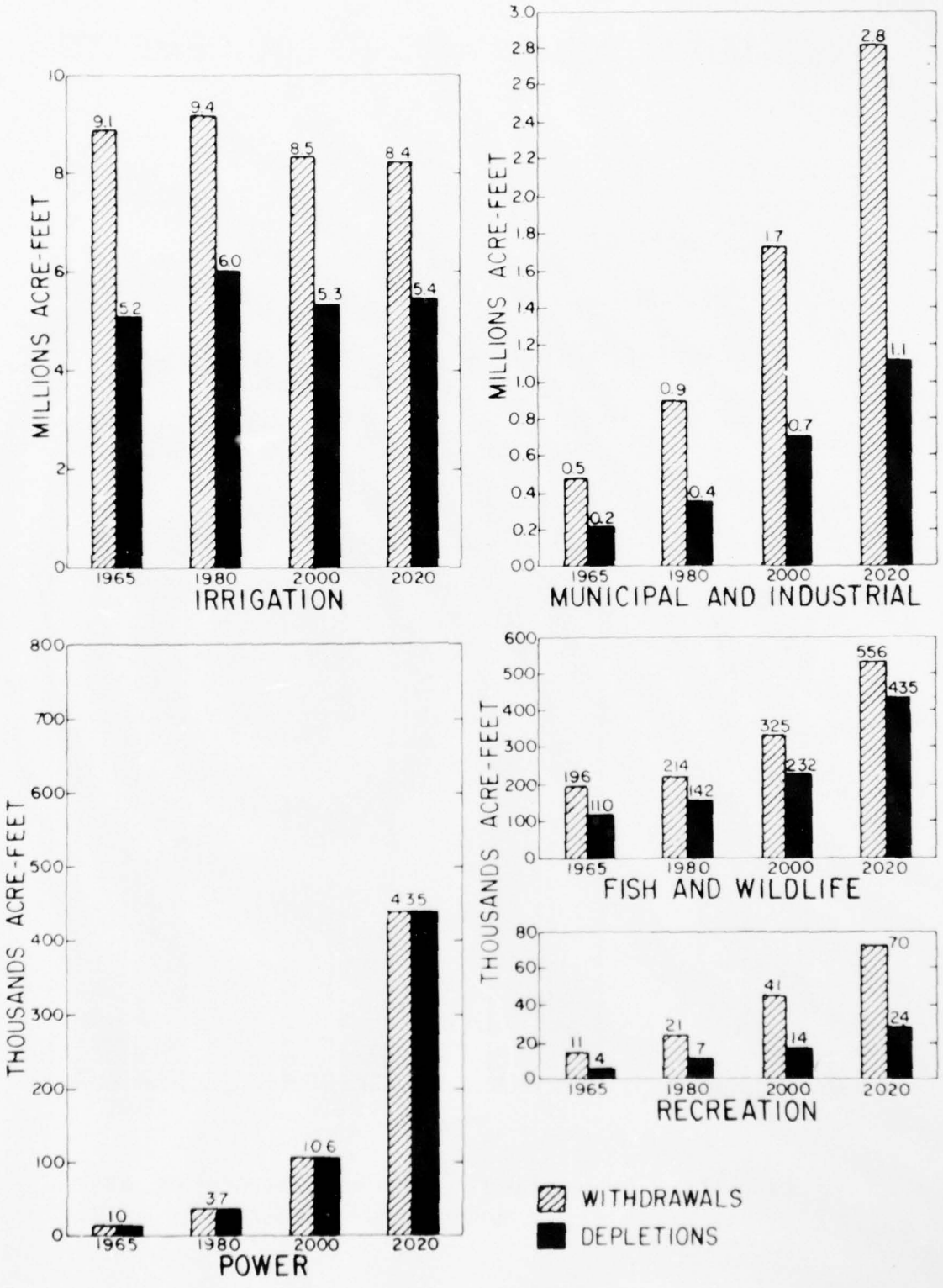


Table 5
Estimated Water Withdrawal and Depletion Requirements (1965 and Projected)
Lower Colorado Region

Unit: 1,000 Acre-Feet

Water Use	Withdrawals				Depletions			
	1965	1980	2000	2020	1965	1980	2000	2020
Reservoir Evaporation 1/	230	286	328	359	230	286	328	359
Mineral Development	105	178	264	357	51	89	135	185
Irrigation 2/	9,138	9,429	8,496	8,405	5,226	5,966	5,312	5,381
Municipal and Industrial	450	863	1,703	2,778	198	358	677	1,149
Recreation 3/	11	21	41	70	4	7	14	24
Fish and Wildlife	196	214	325	556	110	142	233	405
Power	10	37	106	435	10	37	106	435
Total	10,140 4/	11,026	11,264	12,960	5,829	6,885	6,805	7,938

1/ Exclusive of Colorado River Mainstream evaporation.
2/ Includes nonbeneficial consumptive use, estimated as 15 percent of irrigation requirement. Also includes estimated 600,000 acre-feet in-transit water losses in central Arizona area of Gila Subregion (1965 and 1980).
3/ Exclusive of lake and reservoir evaporation losses.
4/ 8,391,000 acre-feet actually withdrawn in 1965, includes 230,000 acre-feet reservoir evaporation.

Note: Columns do not necessarily add to total shown because of rounding.

Little Colorado Subregion

The most vital needs of the Little Colorado Subregion are to supply additional water to its two major cities of Flagstaff, Arizona, and Gallup, New Mexico, to help maintain economic stability and to provide for future growth and additional water to stabilize the present agricultural economy. It would also provide greater employment opportunities for its predominantly rural Indian population through further development of the tourist industry, the attraction of outdoor recreationists, and the encouragement of light industry. The water supply of the Subregion is poorly distributed with respect to the areas of need. Additional water for municipal, industrial, and agricultural uses needs to be made available for several areas in the Subregion.

Gila Subregion

The Gila Subregion is the major water deficient area of the Region. Even though about 2.5 million acre-feet of ground water were mined in 1965, the apparent water requirements were not satisfied. By 2020, the annual withdrawal requirement is expected to increase by more than 1.9 million acre-feet. The increased requirements are due primarily to the needs of an expanding population. Most of the water needs are concentrated in the vicinities of Phoenix and Tucson. Existing sources are essentially completely utilized and only infrequent floods produce outflow from the Subregion. There is a critical need to augment the water supplies of the Subregion to reduce the ground-water overdraft and to meet the increasing water requirements.

There are sufficient suitable lands for each land use when considered separately, but even with the widespread adoption of the multiple-use principles, not all of the requirements may be fulfilled. Competition among land uses is expected to intensify during the study period, causing shifts in land use. Because of the rapid population growth in recent years, major shifts in land use have already occurred adjacent to the major cities in the Region. In the Phoenix area, most urban expansion has been on formerly productive irrigated cropland. Mature citrus groves and land used to grow winter vegetables are being replaced by housing developments. This cropland is replaced by developing rangeland in outlying areas at great expense.

The following table lists 1965 land use and projected land requirements by time frame for each function or land use:

Table 6
Present Use and Projected Land Requirements

Unit: 1,000 Acres

Use	1965	1980	2000	2020
Cropland	1,816	1,891	1,905	1,852
Irrigated	(1,785)	(1,863)	(1,882)	(1,833)
Nonirrigated	(31)	(28)	(23)	(19)
Livestock Grazing	76,054	73,739	69,902	65,807
Timber Production	5,458	5,358	5,153	5,044
Urban and Industrial	513	863	1,230	1,564
Outdoor Recreation (designated)	5,542	5,888	6,012	6,146
Wilderness Areas	861	1,458	3,158	3,458
Fish and Wildlife (designated)	3,223	3,546	7,175	15,020
Military	4,126	4,126	4,126	4,126
Transportation and Utilities	660	858	1,030	1,145
Mineral Production	75	115	156	223
Water Yield Improvement	114	289	824	1,229
Flood Control	77	229	289	336

Rapid urban expansion envelopes prime irrigated agricultural lands in the Phoenix area.

LAND TREATMENT AND MANAGEMENT

An appraisal of future land treatment and management requirements was made assuming that all land use will be based on sustained or increased production without deterioration of the land and water resources.

Erosion and sedimentation processes are major problems in the Region. Soil erosion causes various types of damage as does sediment, the product of erosion. Erosion causes such damage as land loss and loss in land productivity, decreases recreation values and the quality of fish and wildlife habitat, and in most cases, blemishes the esthetic value of the landscape. The 1965 average annual erosion damage of $6.7 million, without additional protection measures or works of improvement installed after 1965, is projected to increase to $24.1 million by 2020.

There is a need for the treatment of mountain watershed lands to increase and regulate water yield in order to help fulfill the ever-increasing water requirements.

Control of wildfire is basic to the development and utilization of nearly all resources, activities, and uses of the forest and rangelands of the Lower Colorado Region. The 1965 average annual damage from this source of $5.7 million, with no intensification of the wildfire protection program, is projected to increase to about $20.0 million by 2020.

Area of severely eroded grazing land.

FLOOD CONTROL

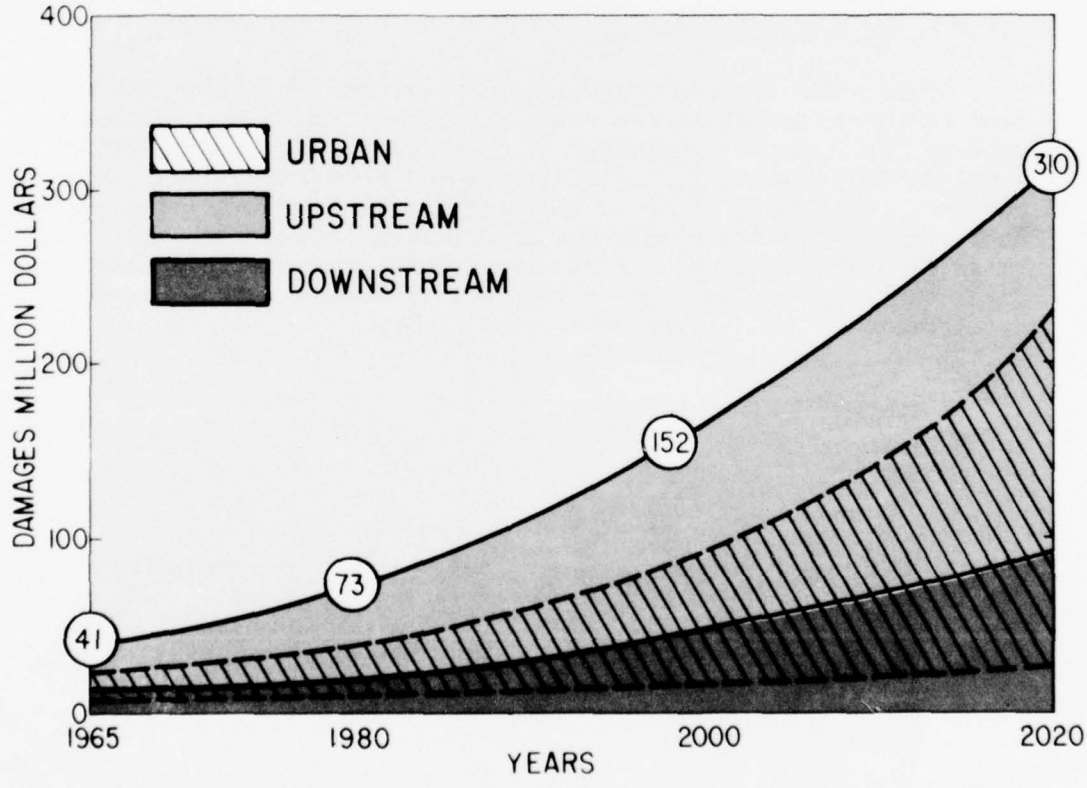
A major part of the Region's presently developed urban area and productive cropland is on lands subject to periodic flooding. Most land having topography suitable for general development within the Region is subject to flooding whether near a defined stream or not. It is expected that most future development, whether urban or agricultural, will need some degree of flood protection. In 1965, there were approximately 164,000 acres of urban land and over one million acres of cropland subject to flooding within the Region. In addition, about 4.3 million acres of forest and rangeland are subject to flooding.

Flood damages are classified as either downstream or upstream. In general, downstream flood damages are those occurring on the main stems and major tributaries, and upstream flood damages are those experienced on the smaller tributaries (having drainage areas of less than 250,000 acres).

Based on the 1965 level of flood plain development and protection, average annual flood damage within the Region is estimated to be about $41 million. Of this amount, approximately $22 million is agricultural damage and $19 million is nonagricultural damage. Of the total damage, 30 percent is in downstream areas and 70 percent is in upstream areas 1/. Past trends have shown that flood damages generally increase when there is a rise in economic development. Virtually all economic projections indicate continued development of land in the Lower Colorado Region. With protection at the 1965 level, the expansion of the economy and projected growth in the area subject to flooding would increase total flood damage to $310 million by 2020 as shown in Figure 13. The annual agricultural damages would increase from $21 million to $61 million and the nonagricultural damages would increase from $20 million to $249 million. The nonagricultural damages include $13 million urban damages in 1965 and $201 million in 2020.

1/ (a) This presentation of flood damage data by upstream-downstream areas in no way determines the agency responsible for the solution of the flood damage problems; and (b) data presented include major urban damages in upstream areas.

FIGURE 13
PROJECTED ANNUAL FLOOD DAMAGES
WITHOUT ADDITIONAL FLOOD CONTROL MEASURES

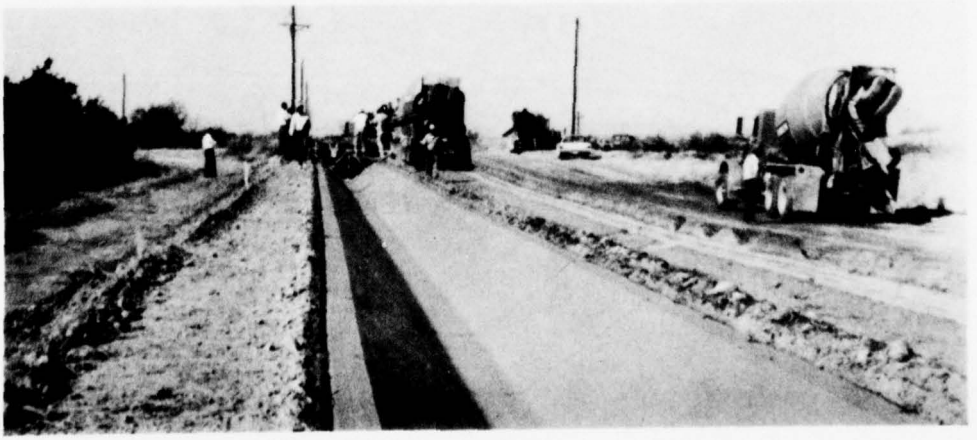


IRRIGATION AND DRAINAGE

The Lower Colorado Region has over 36 million acres suitable for irrigated agriculture of which only about 5 percent is projected to be utilized for crop production.

Projections indicate that about 204,000 acres of land presently developed for irrigation will be converted to urban development by the year 2020. To compensate for this loss of irrigated acreage and to provide a net increase of 298,000 acres of irrigated land, about 502,000 acres of new irrigation development need to be accomplished before the year 2020. Expected new land development for irrigation during the study period would include: lands in 14 Indian reservations, in authorized projects in Utah, and private development in outlying ground-water basins.

Other needs include installation of onfarm irrigation water management practices and measures, rehabilitation of existing distribution systems, drainage development, and development of new distribution systems on both existing irrigated land and new irrigated land. Each contract under which water is provided by the Central Arizona Project must require that the canals and distribution systems through which water is conveyed be maintained with linings adequate to prevent excessive conveyance losses. Table 7 shows the total required irrigation development and net increases by time frame.



Lining of distribution ditches is necessary
for increased efficiency of irrigation water use.

Table 7
Irrigation and Drainage Projected Requirements
(Modified OBE-ERS)

	1966-1980	1981-2000	2001-2020
	------- 1,000 acres --------		
New Irrigation Development	200	168	132
Increased Irrigated Area	(172)	(91)	(33)
Urban Replacement	(28)	(77)	(99)
Rehabilitation of Existing Irrigation Distribution System 1/	429	-	-
Development of New Irrigation Distribution System 2/	347	596	132
Irrigation Water Management 3/	573	801	782
Drainage Needs 4/	68	32	88

1/ Requirement to deliver water to farm.

2/ Includes replacement for irrigated area utilized in urban expansion.

3/ Includes retreatment on most areas because of limited life of the practice and/or measure and improved technology.

4/ Group drainage needs.

MINERAL REQUIREMENTS

The value added by the mineral industry is projected to increase from over $317 million in 1965 to about $895 million by the year 2020. Copper is expected to remain the dominant mineral in the Region, comprising 60 to 65 percent of the total copper produced nationwide. The output of byproducts of copper, such as molybdenum, silver, and gold, is expected to parallel copper output. The production of sand and gravel and cement is expected to increase parallel to population growth and its subsequent needs for building and construction materials.

MUNICIPAL AND INDUSTRIAL WATER

A projected 370 percent increase in population, a sixteenfold increase in the value of manufacturing output, a fifteenfold increase in the economic activity in the trade and services sectors, and rising water-use rates by the Region's Indian and other rural residents are the major reasons for the tremendous growth of municipal and industrial water requirements shown on Figure 12, page 70. When compared to 1965 requirements, the 2020 annual depletions and withdrawals will increase by 0.9 million and 2.3 million acre-feet, respectively.

The increase in livestock water requirement will be greater than 0.02 million acre-feet by 2020. The projected increase in range livestock is slight. Feeder livestock, on the other hand, are projected to increase significantly over the study period.

RECREATION

The total demand for outdoor recreation is projected to increase from 138 million to 918 million recreation days between 1965 and 2020. The greatest recreation pressures are expected to be exerted on resources in the Gila Subregion because of the present and projected population concentrations there. About 70 percent of the total recreation demand is urban oriented which means that this demand should be supplied within an hour travel time of the urban centers. Of the total projected demand, about 27 percent is water-based (comprising activities requiring water, such as swimming, boating, fishing, water skiing, sailing, and canoeing). Figure 14 illustrates graphically the projected recreation demand.

FIGURE 14
PROJECTED RECREATION DEMAND

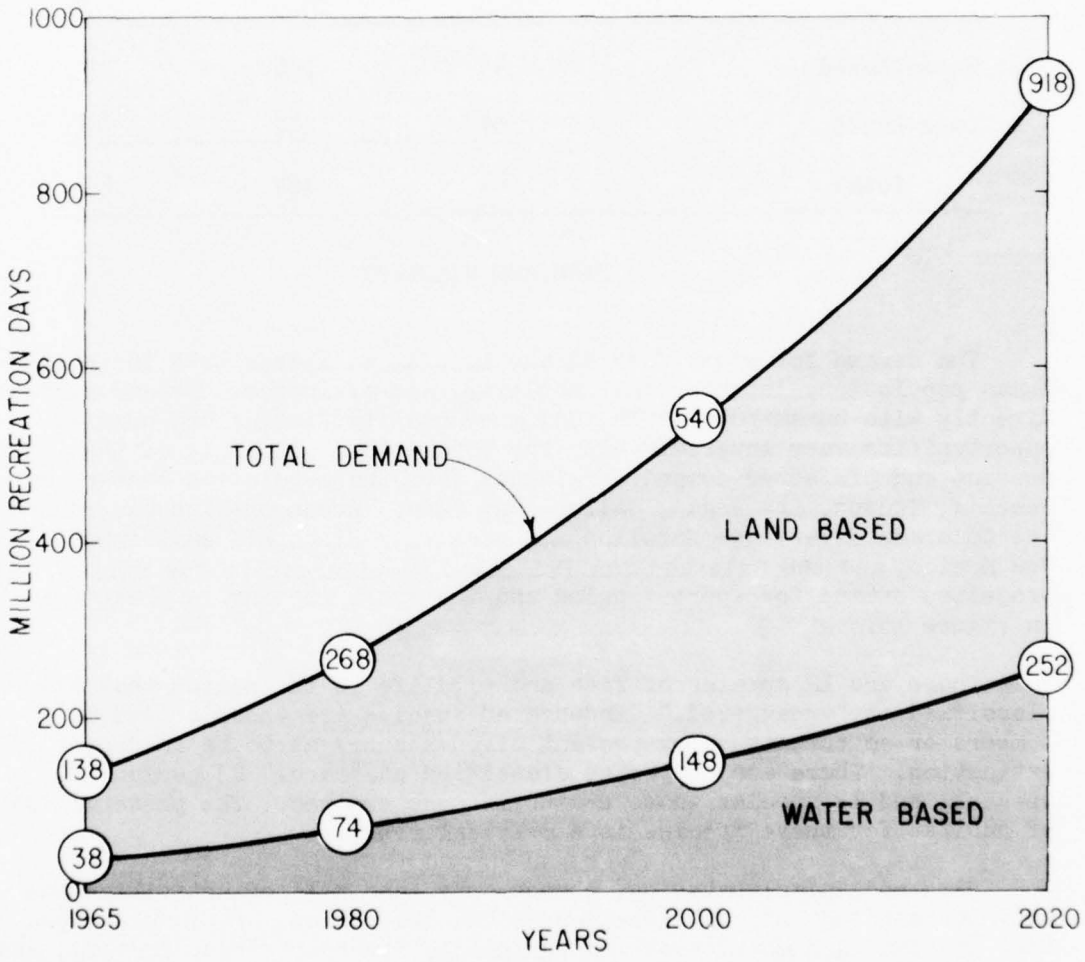


Table 8 shows the total recreation needs by time frame separated into water-based and land-based. Recreation need is that part of projected demand not satisfied by the 1965 resource base.

Table 8
Projected Annual Recreation Needs
Lower Colorado Region

	1980	2000	2020
Water-Based	43	106	193
Land-Based	101	258	478
Total	144	364	671

FISH AND WILDLIFE

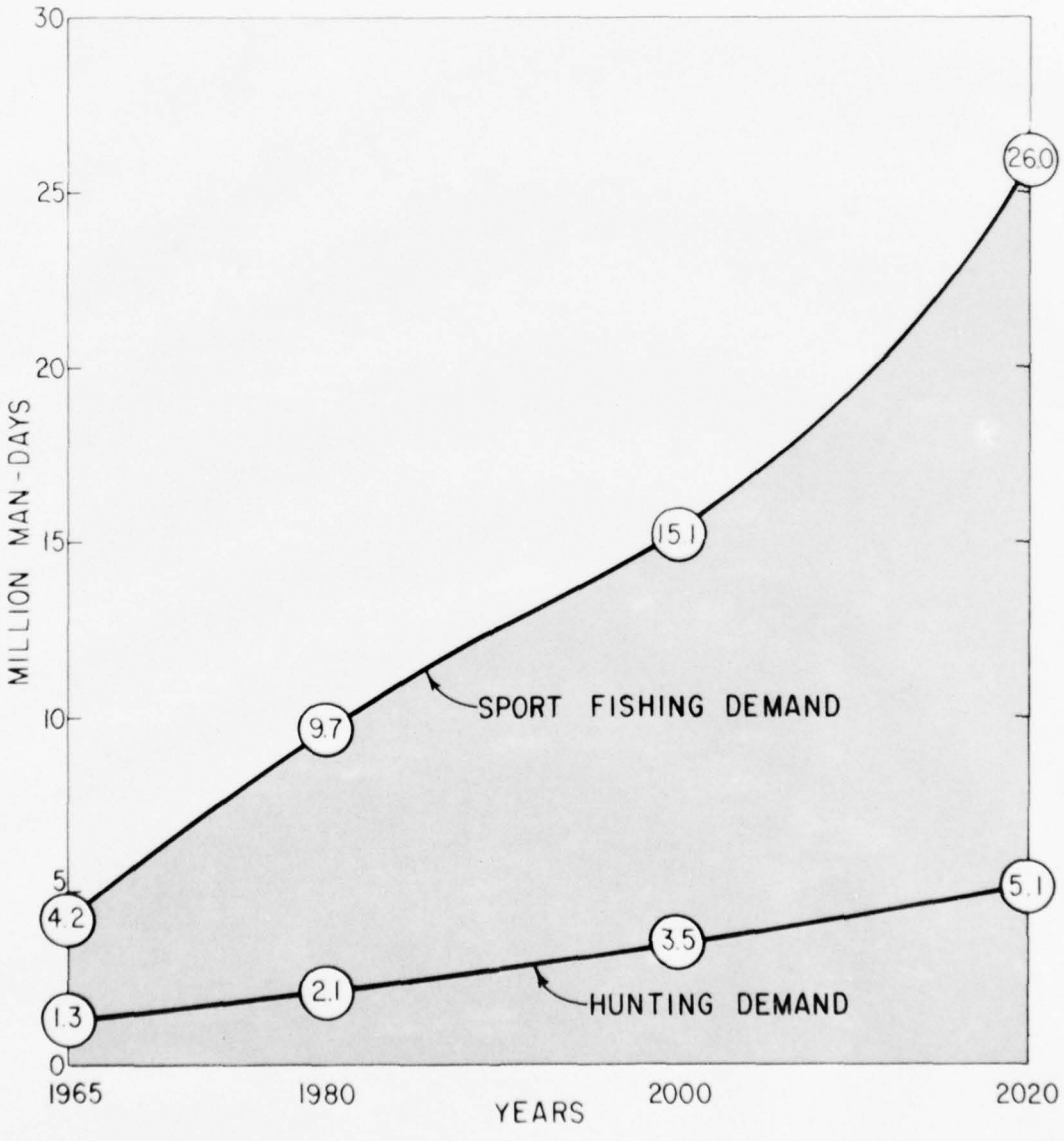
The demand for sport fishing and hunting will grow with increasing human population, leisure time, mobility, and affluence. Demand varies directly with human population, and good quality fishing and hunting opportunities vary inversely with the population. The bulk of the present and projected demand originates from the population centers of Phoenix, Tucson, Las Vegas, Gallup, and Yuma. Areas of high use include the Colorado River, the Mogollon Rim area from Flagstaff east into New Mexico, and the Gila and San Francisco River areas in New Mexico. The projected demand for sport fishing and for sport hunting is presented in Figure 15.

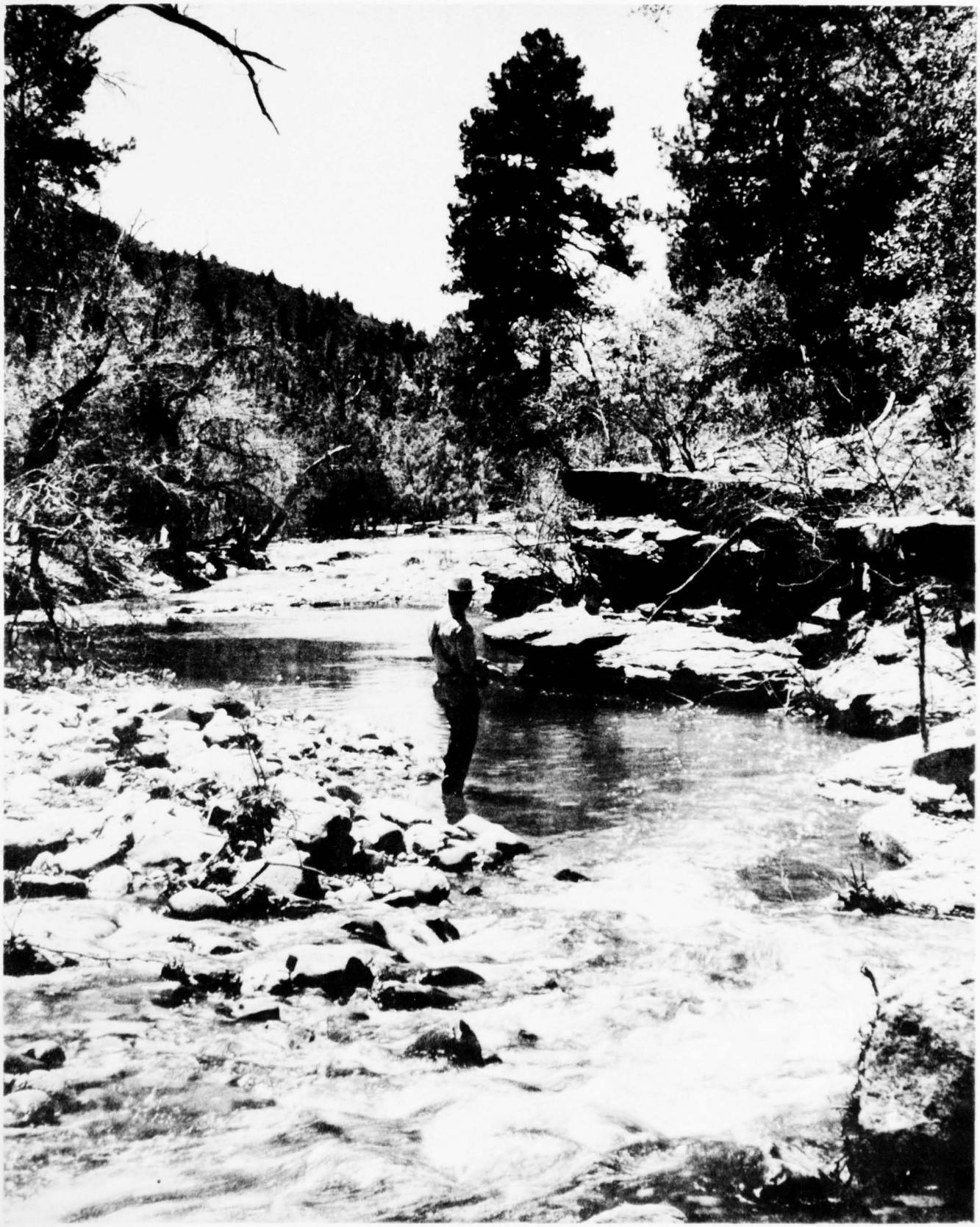
There are 12 species of fish and wildlife in the Region that are classified as "endangered." Endangered species are those so few in numbers or so threatened by present circumstances as to be in danger of extinction. There are 6 species classified as "rare," 23 peripheral species, and 13 species whose status is undetermined. The preservation of habitat for these species is a critical need.

Bird and animal watching, photography, and related activities are an important segment of wildlife-oriented recreation. It is estimated that the time and money spent on equipment, transportation, lodging, and related items associated with observing fish and wildlife resources eventually may approach that expended by hunters.

FIGURE 15

PROJECTED SPORT FISHING AND HUNTING DEMANDS





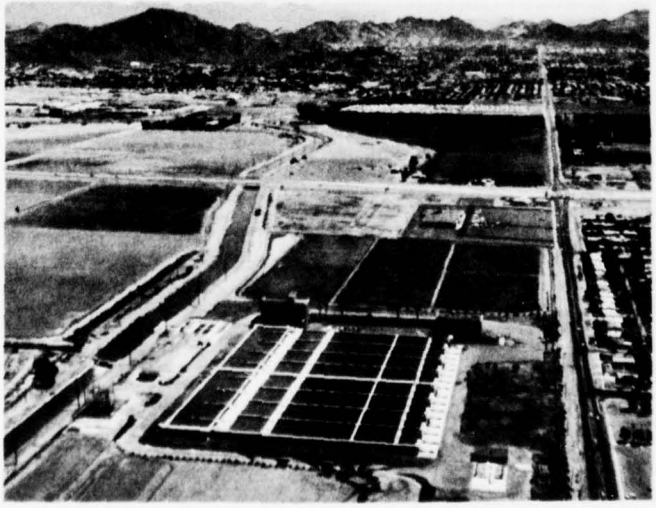
WATER QUALITY, POLLUTION CONTROL, AND HEALTH FACTORS

The major water quality problem existing in the Lower Colorado Region is the heavy burden of dissolved salts carried by regional streams. The salinity of surface waters, and, in many cases, ground water, causes major problems to irrigated agriculture and to municipal and industrial users of water. Substantial future increases in salinity are to be expected, unless significant changes in water quality management are initiated, or unless water supplies are augmented, thereby providing additional water for dilution.

There is a need to improve the present level of waste water treatment and to add advanced methods of treatment in the larger metropolitan areas to minimize the effects of pollution from municipal and industrial wastes and to provide a water quality suitable for other uses.

Soil erosion is a cause of water pollution. Not only are eroded soil particles carried into water, but along with them may be pesticides, fertilizers, and other materials picked up from the land surface. Extensive treatment may be needed to make the water supply suitable for household and industrial uses. Muddy water also often upsets the ecology of a stream reducing its recreational potential and fish-sustaining capability.

In order to prevent the spread of infectious diseases resulting from increased pressures on environmental resources, programs for the protection of the public health will need to be expanded to keep pace with population growth. Adequate safeguards will be necessary to protect the public health from water pollution, air pollution, disease-carrying rodents and insects, and possible radiological hazards from the expected use of nuclear fuels for the production of electric power.



Modern water treatment facility, Phoenix, Arizona.

ELECTRIC POWER

To serve the growing consumer demands in the Region, the addition of future generating facilities will be needed. Existing transmission of electric power in the Region is characterized by long distances between hydro or remotely located thermal power sources. This pattern is expected to continue until the year 2000, by which time nuclear power plants are expected to be in operation. It is anticipated that with advancements in nuclear technology, nuclear plants would be located nearer to consumers than the present hydro and thermal plants. Total electric energy requirement projections developed by the Federal Power Commission for the Lower Colorado Region are depicted on the following graph:

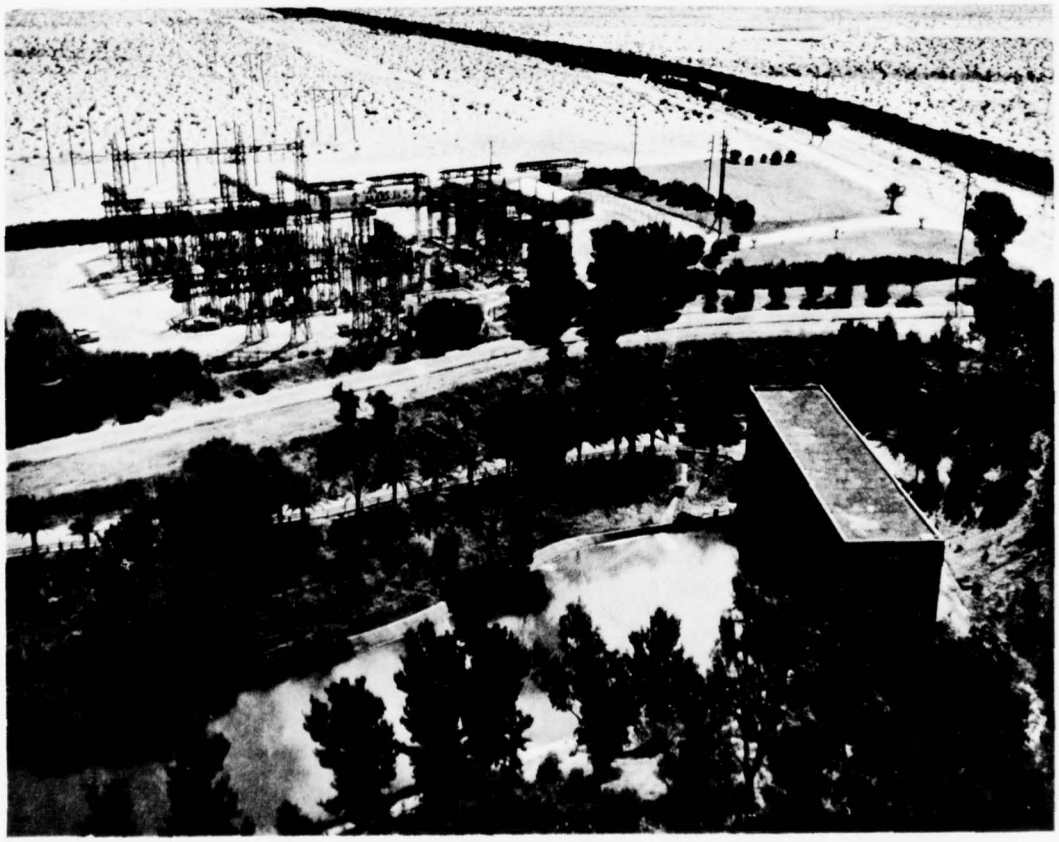
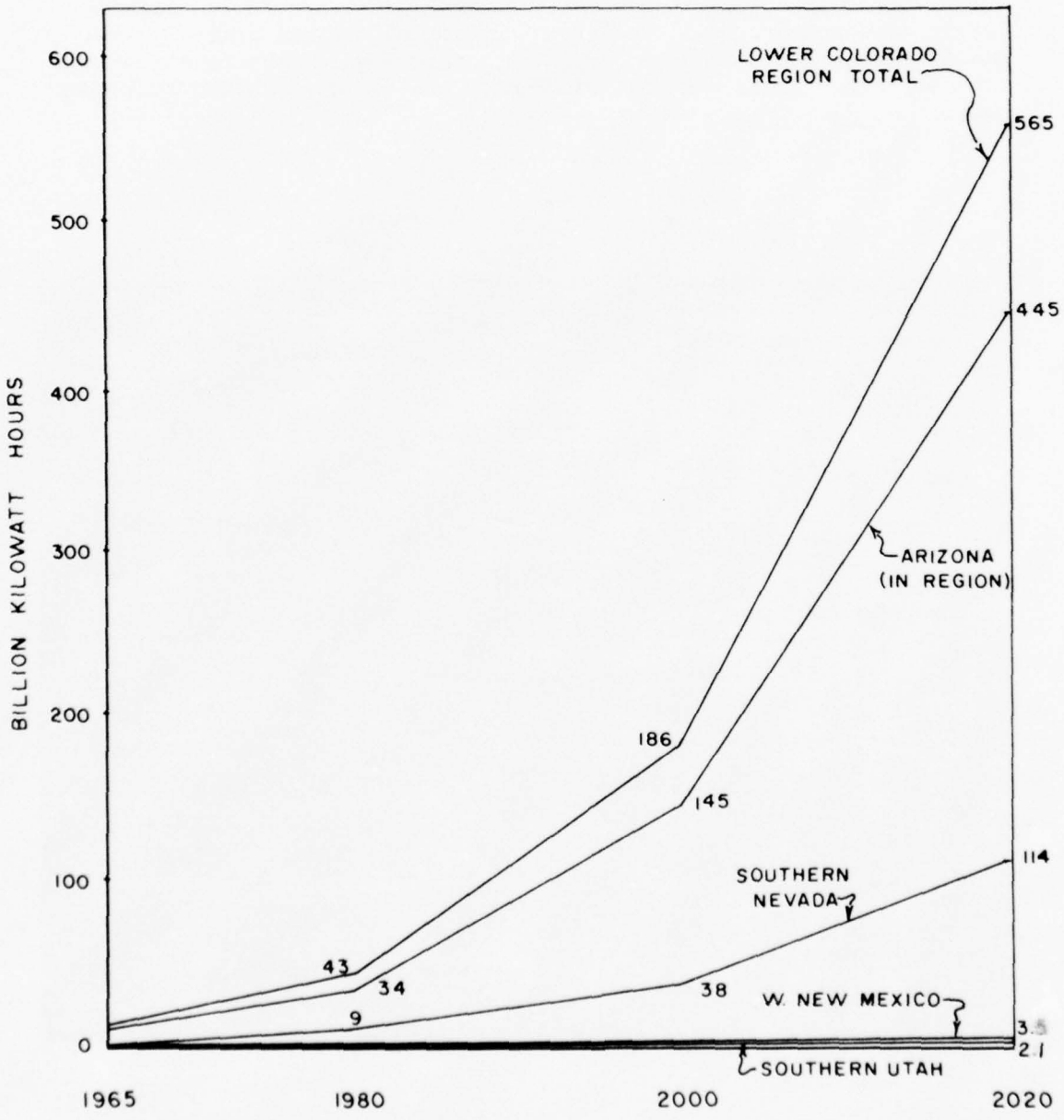


FIGURE 16
PROJECTED ELECTRIC ENERGY REQUIREMENTS



REGIONAL COMPREHENSIVE FRAMEWORK PROGRAM

CHAPTER G - REGIONAL COMPREHENSIVE FRAMEWORK PROGRAM

PLANNING CONSIDERATIONS

The foremost consideration in long-range planning for the Lower Colorado Region is the development of a framework within which future developments will provide the water that is so crucial not only to the preservation of the present level of development, but also to future growth. Equally important to the satisfaction of the socio-economic needs is the protection, preservation, and enhancement of the Region's resources such as land, water, minerals, wildlife, wildernesses, recreation, archeological, historic, and esthetic values, livestock forage, timber, and other resources.

The development of such a comprehensive framework program requires that a proper balance be established between all segments of the program to minimize detrimental impacts. To ascertain the best combination of programs, consideration of all practicable alternatives is necessary and many optional mixes of these should be examined.

Comprehensive planning on this scale should not be unduly influenced by cost considerations because even though some environmental aspects elude monetary evaluation, they are equally important to components that can be readily and accurately evaluated.

More specific concepts, assumptions, constraints, and guidelines have been previously discussed in the introductory chapter of this report.

Estimated costs for the framework program developed herein are presented in the Summary of Findings.

DEVELOPMENT OF THE PROGRAM

Because of time limitations, it was not possible in this study report to examine, in detail, as many of the potential alternatives as desirable. Many alternatives were considered and some are recommended for future studies. The recommended program stems from the reasoned judgments of experienced planners in many disciplines participating in the study.

Two projected levels of development were considered in project formulation (OBE-ERS and modified OBE-ERS levels). The significant differences in the two levels are outlined in the Alternative Levels of Development chapter.

This program is based on the modified OBE-ERS projected level of development and is designed to satisfy as much of the individual functional demands as practicable. Some remaining demands, unmet by multipurpose development, are treated as primary-purpose items in the framework program.

In keeping with the guidelines set out for this study, the present and projected requirements for services, products, environmental development, and resource development were all given consideration.

The annual volume of import of water required was calculated to satisfy all stated needs. Equal priority was given to all water uses.

EARLY ACTION PROGRAM, 1965 - 1980

Multipurpose Water Supply

The early action program objective is to fully utilize all surface water supplies available to the Region, seek every means of conserving water for beneficial use, to explore the effects of ground-water overdraft, and investigate possibilities of untapped ground-water reserves that might be utilized as an interim measure until augmentation from sources outside the Region could be achieved.

Presently authorized water supply projects included in the 1965 to 1980 framework program include the following: the Central Arizona Project, a multipurpose project which will provide facilities to convey up to 1.67 million acre-feet of Colorado River water to central Arizona; the Southern Nevada Water Project which will initially provide facilities to convey 0.13 million acre-feet of water from Lake Mead to the Las Vegas, Nevada, metropolitan area for municipal and industrial uses and provides for additional stages, which may be altered or relocated as required; and the Dixie Project which will provide supplemental and new irrigation water in addition to water for municipal and industrial uses in southern Utah. Tertiary treatment facilities would make available 260,000 acre-feet of waste water for direct reuse.

Also to be provided, by authorized projects during this time period, is the recovery of approximately 270,000 acre-feet annually along the Colorado River which are now being used by the total natural river-associated ecosystem. In addition, 35,000 acre-feet of water can be

recovered annually from the Gila River by phreatophyte control. The Early Action Program 1965 - 1980 is shown on the map following page 92.

There are 9 reservoirs presently authorized or under construction in the Region totaling nearly 3.9 million acre-feet of capacity. The primary purpose of 6 of the reservoirs is conservation storage associated with the Central Arizona and Dixie Projects. The remaining 3 would be primarily for flood control purposes.

The 1965 to 1980 land treatment and management program provides water yield improvement measures on about 175,000 acres of chaparral and coniferous forest lands to increase average annual water yield by about 30,000 acre-feet. Means to conserve and more efficiently utilize existing water supplies are also included in the early action program. After implementation of the early action program, a water supply deficiency of about 1.5 million acre-feet will remain.

Water Quality

A Colorado River Basin Salinity Control Program is necessary to prevent further quality degradation of Colorado River water entering the Lower Colorado Basin. In the absence of controls, the concentration of total dissolved solids at Lee Ferry is projected to increase from 586 milligrams per liter to 650 milligrams per liter during the 1965 to 1980 period, and at Imperial Dam, from 839 to 1,260 during the same time period.

The early action water quality program provides facilities for additional treatment of municipal and industrial wastes in the Las Vegas, Nevada, and Phoenix-Tucson, Arizona, areas. Provisions for reuse of reclaimed water are also provided. The Colorado River Basin salinity control program provides for the impoundment and evaporation of flows from LaVerkin Springs in Utah, which will prevent more than 100,000 tons of salt annually from reaching the Colorado River.

Land Treatment and Management

The land treatment and management program is needed to minimize irreversible losses of the land resources and to preserve the freedom of choice for future resource users. The program includes treatment of 19.3 million acres by 1980 at a total cost of about $205.7 million.

Cropland--Measures such as diversions, levees and dikes, channel improvement, floodways, and streambank protection were considered for erosion, sediment, and runoff control on cropland. Necessary soil surveys are also included. These measures are primarily for protection of the land and improvements, but also help to maintain and/or improve the

productivity of the land. The program provides for treatment of 153,000 acres of cropland between 1966 and 1980 at a total cost of $3.5 million.

Rangeland--Measures considered in developing an effective land treatment and management program on rangeland consist of (1) small structural measures such as grade stabilization structures, diversions, and terraces; (2) vegetative measures such as grass, tree, and shrub plants; and (3) intensive management. The orderly and efficient use of water, land, and other resources is necessary for successful multiple-use production while protecting and improving environmental values. The program was designed to reduce sediment yield, reduce wildfire damage, improve water quality and/or quantity, and increase the productive ability of the land. Included in the program is treatment of 15.3 million acres of rangeland at a total cost of $80.9 million between 1966 and 1980.

Forest Land--Programs for development and management of forest land and resources are designed to utilize and maintain or improve the total productive capacity of the land and water, including wood, forage, recreation, wildlife, and water to meet the regional and national needs of the people.

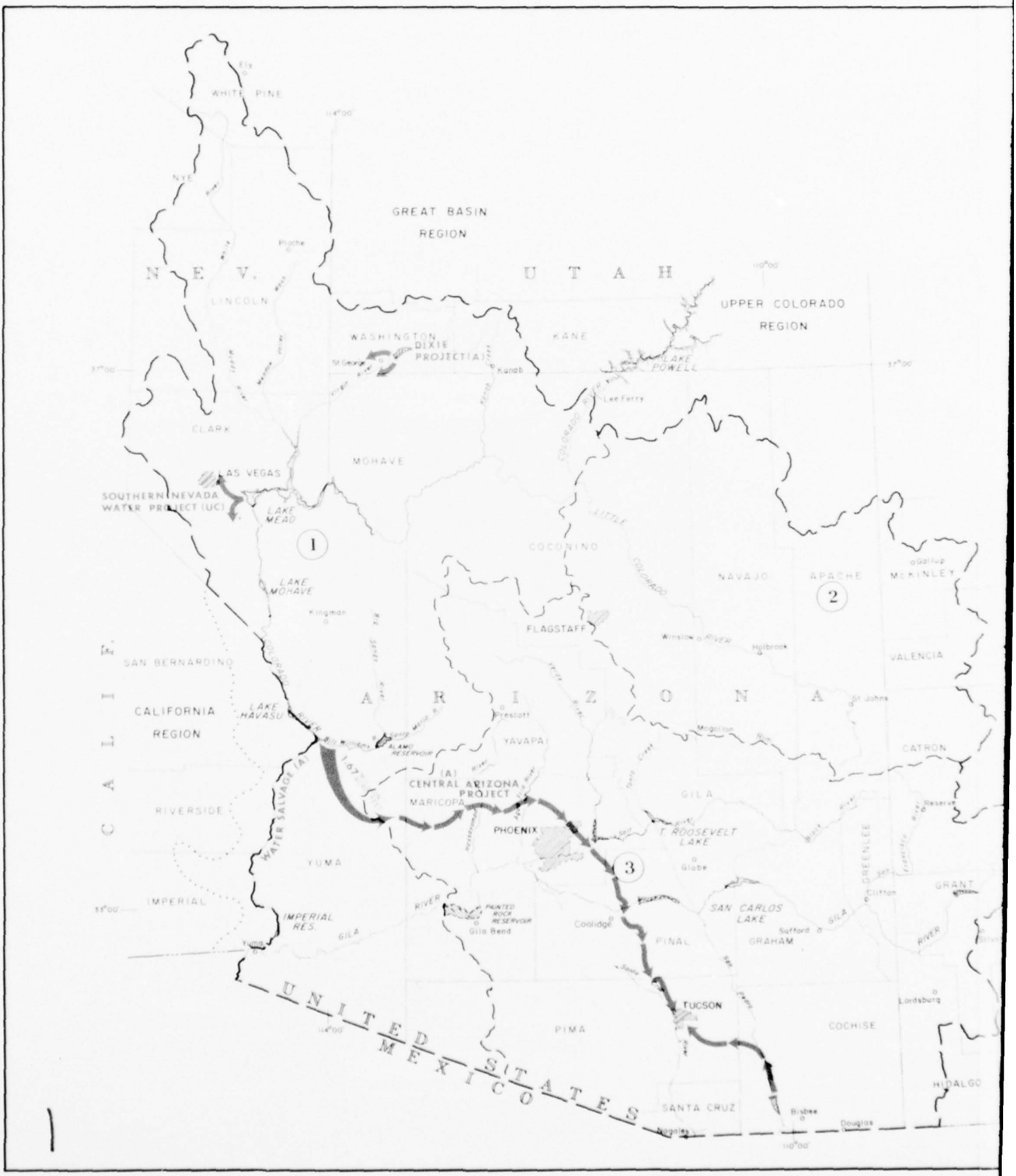
These progams include thinning, reforestation, insect and disease control, for increasing wood production; conversion of woodland and chaparral, for increasing forage; management of vegetation, resources, and activities, for the enhancement of the recreation resources including esthetic and environmental values; management of vegetation for improved water quality; and vegetative management for increasing water yield.

About 3.6 million acres of forest land in the Region are included for treatment, at an estimated cost of $115.8 million, between 1966 and 1980.

Urban and Other--Measures such as diversions, levees and dikes, channel improvement, floodways, and establishment of vegetation were considered for erosion, sediment, and runoff control in urban and mined areas, and along roadsides, utility rights-of-way, etc. A total of 182,000 acres of urban and other lands would receive treatment between 1966 and 1980 at a total cost of $5.5 million.

Flood Control

The flood damage reduction program includes measures for the control of water and the controlled use of the flood plain. Structural measures used to control the flow of water include reservoirs and retarding structures, levees, and channel improvements. Nonstructural measures include flood forecasting, evacuation, and flood plain regulation involving zoning ordinances, building codes, open space requirement, development policies, subdivision regulations, tax adjustments, and warning signs.


GREAT BASIN
REGION
UPPER COLORADO
REGION
CALIFORNIA
REGION
NEV.
UTAH
ARIZONA
WHITE PINE
NYE
LINCOLN
CLARK
WASHINGTON
KANE
MOHAVE
COCONINO
NAVAJO
APACHE
MCKINLEY
SAN BERNARDINO
RIVERSIDE
IMPERIAL
YUMA
LA PAZ
YAVAPAI
MARICOPA
PINAL
GILA
GRAHAM
GREENLEE
GRANT
CATRON
VALENCIA
PIMA
COCHISE
SANTA CRUZ
HIDALGO
DIXIE PROJECT (A)
SOUTHERN NEVADA WATER PROJECT (UC)
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
LAKE POWELL
(A) CENTRAL ARIZONA PROJECT
WATER SALVAGE (A)
IMPERIAL RES.
PAINTED ROCK RESERVOIR
ALAMO RESERVOIR
T. ROOSEVELT LAKE
SAN CARLOS LAKE
LAS VEGAS
PHOENIX
TUCSON
FLAGSTAFF
Ely
Pioche
St George
Kanab
Lee Ferry
Kingman
Prescott
Holbrook
Winslow
St Johns
Globe
Coolidge
Gila Bend
Safford
Clifton
Lordsburg
Bisbee
Douglas
Nogales
Yuma
Gallup
Reserve
Show Low
Silver City
UNITED STATES
MEXICO
1
2
3
110°00
114°00
37°00
35°00

INDEX MAP

UPPER COLORADO REGION

LAKE POWELL

NAVAJO

APACHE

2

GALLUP

MCKINLEY

VALENCIA

CATRON

GILA

ST ROOSEVELT LAKE

GLOBE

3

GREENLEE

CLIFTON

GRANT

SAN CARLOS LAKE

SAFFORD

GRAHAM

PINAL

SILVER CITY

RIO GRANDE REGION

TUCSON

LORDSBURG

COCHISE

HIDALGO

SANTA CRUZ

BISBEE

DOUGLAS

NOGALES

EXPLANATION

- Lower Colorado Region boundary
- Subregion boundary
- (1) Lower Main Stem
- (2) Little Colorado
- (3) Gila
- Lower Colorado Basin boundary
- Existing dam and reservoir
- Existing dam and intermittent lake
- Potential Development 1965-1980
- (A) Authorized project
- (UC) Project under construction

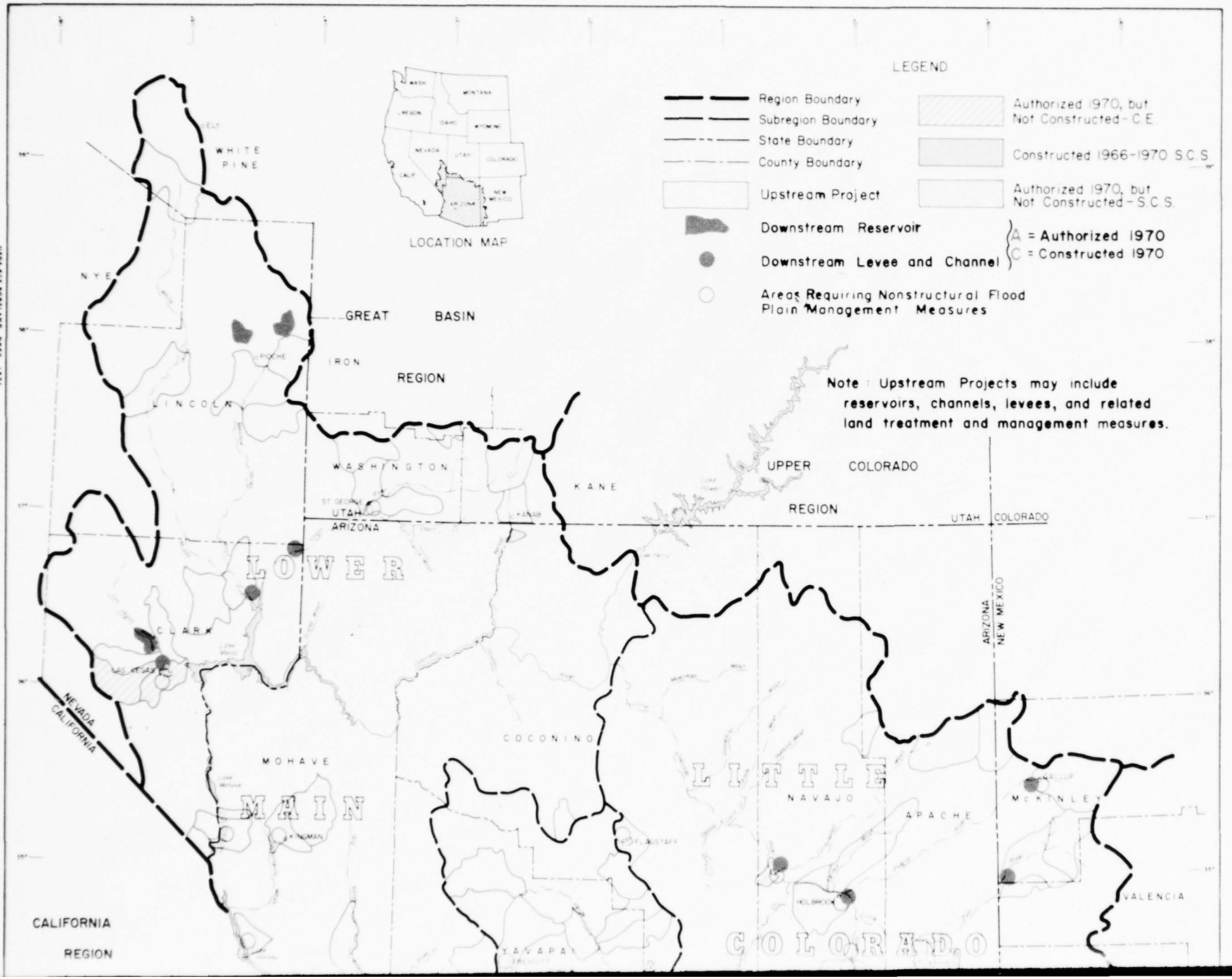
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

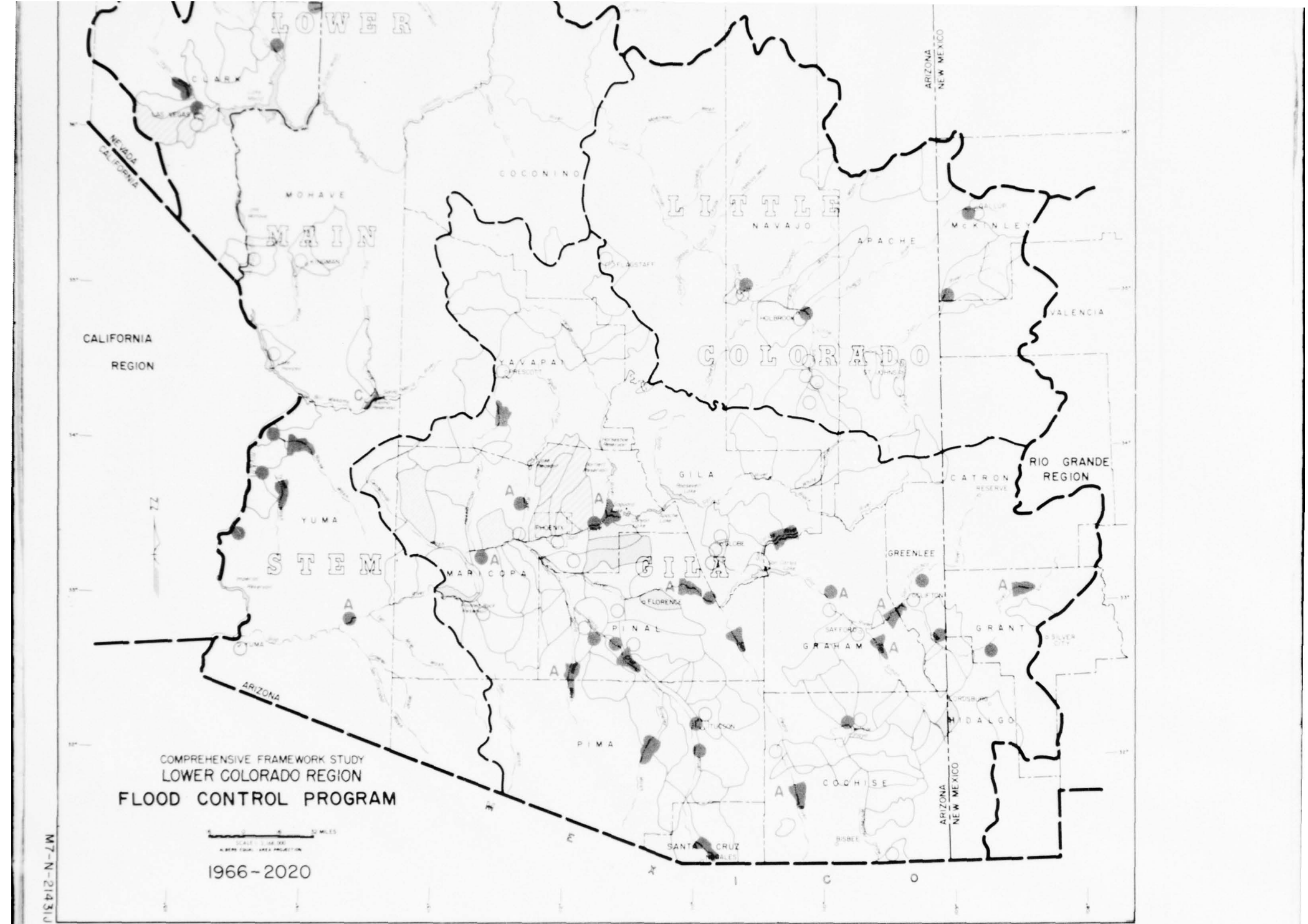
POTENTIAL WATER RESOURCE DEVELOPMENT
EARLY ACTION PROGRAM
1965-1980

MAP NO. 1019-300-1

SCALE OF MILES

NOVEMBER 1970


LEGEND
Region Boundary
Subregion Boundary
State Boundary
County Boundary
Upstream Project
Downstream Reservoir
Downstream Levee and Channel
Areas Requiring Nonstructural Flood Plain Management Measures
Authorized 1970, but Not Constructed - C.E.
Constructed 1966-1970 S.C.S.
Authorized 1970, but Not Constructed - S.C.S.
A = Authorized 1970
C = Constructed 1970
LOCATION MAP
Note : Upstream Projects may include reservoirs, channels, levees, and related land treatment and management measures.
GREAT BASIN REGION
UPPER COLORADO REGION
LOWER MAIN
LITTLE COLORADO
CALIFORNIA REGION
WHITE PINE
NYE
LINCOLN
IRON
WASHINGTON
KANE
CLARK
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
YAVAPAI
UTAH
ARIZONA
COLORADO
NEVADA
CALIFORNIA
NEW MEXICO


LOWER
MAIN
STEM
GILA
LITTLE
COLORADO
CALIFORNIA
REGION
RIO GRANDE
REGION
NEVADA
CALIFORNIA
ARIZONA
NEW MEXICO
CLARK
MOHAVE
COCONINO
NAVAJO
APACHE
McKINLEY
VALENCIA
YAVAPAI
GILA
CATRON
RESERVE
YUMA
MARICOPA
PHOENIX
GREENLEE
PINAL
FLORENCE
GRAHAM
SAFFORD
GRANT
SILVER CITY
HIDALGO
PIMA
TUCSON
COCHISE
SANTA CRUZ
NOGALES
BISBEE
ARIZONA
NEW MEXICO
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
FLOOD CONTROL PROGRAM
1966-2020
M7-N-2143J

Channel improvements and levees were provided in the program where they were considered the most practical solution for satisfying the flood protection needs. The early action program includes 273 miles of levees and 586 miles of channel improvements. The program also includes land treatment and management practices that reduce damaging peak runoff on 188,000 acres, and the use of nonstructural measures in flood plain management as a means of preventing damage from floodwaters. The total flood control program is shown on the map following page 92.

By 1980, the program would reduce flood damages by $32 million annually, and the estimated remaining damages would be $41 million annually. The total cost of the program would be $359 million.

Irrigation and Drainage

The early action irrigation program includes increased conservation of existing water supplies, more efficient utilization of lands developed for irrigation and new irrigation development of 200,000 acres, of which 110,000 acres would be on Indian lands.

The program includes completion by 1980 of the ongoing rehabilitation of irrigation water conveyance systems to facilitate more efficient utilization and the conservation of water supplies. Facilities included in the authorized Central Arizona and Dixie Projects will provide: additional water for lands presently developed for irrigation; a full water supply for irrigation of some new lands in Utah; and regulatory storage to facilitate more efficient utilization of water supplies.

Water management measures, such as land leveling, ditch lining, water control structures, and pipelines, are included for better control and more efficient onfarm use of irrigation water and/or to reduce costs of irrigation. A total of 573,000 acres of cropland will be treated by 1980 at a total cost of $56.3 million.

During the period 1966 to 1980, the irrigated harvested acreage is projected to increase from 1.32 million to 1.49 million acres. A portion of the increase would result from the reduction of crop failures (by 55,000 acres). A minor amount of additional irrigation is expected in outlying ground-water basins. Though the irrigated lands harvested will increase by 228,000 acres, the total acreage irrigated will increase only 173,000 acres, and increased water utilization efficiencies will result in increased water withdrawal requirements of only 340,000 acre-feet. Additional drainage facilities are provided to serve 68,000 acres at a cost of $13.4 million.

Municipal and Industrial Water

Projects presently under construction or authorized for construction supply most of the municipal and industrial water in the early action program and will provide 446,000 acre-feet of water by 1980. These projects will provide water for municipal and industrial uses to the major population centers of Las Vegas, Nevada, and Phoenix and Tucson, Arizona, and the less populated area of Washington County, Utah. Two of the projects are multipurpose in scope and one, the Southern Nevada Water Project, meets only municipal and industrial needs.

Desalting facilities, included in the early action program to treat brackish water for 8 municipalities, would have a total capacity of 18 million gallons per day to supplement present supplies. Other communities are expected to meet most of their water needs through 1980 by continued development of ground-water resources.

Recreation

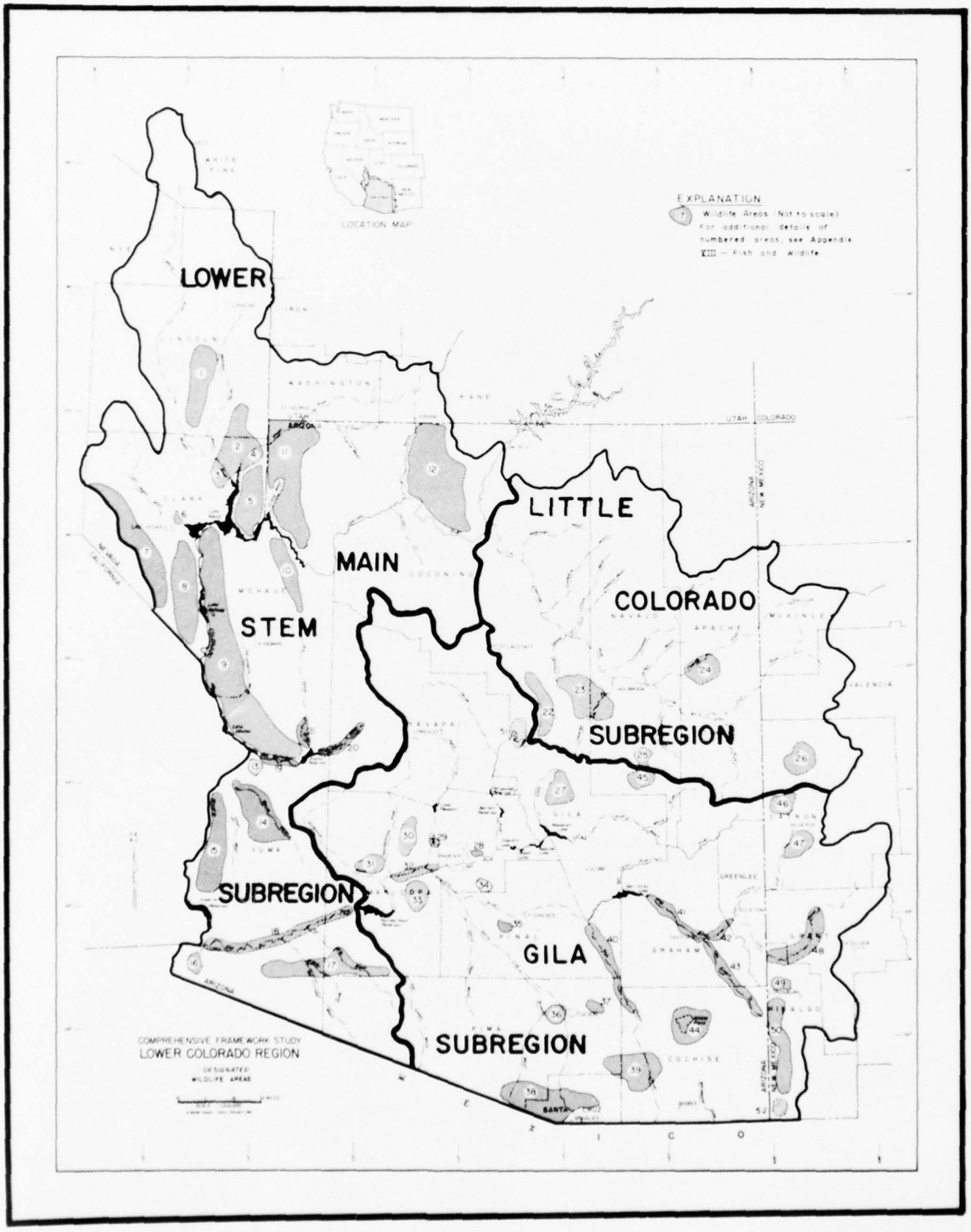
The single-purpose recreation program is essentially one of land acquisition, facility development, and operation, maintenance, and replacement. By the year 1980, about $194 million for development and acquisition will be required to meet total recreation needs of 51 million recreation days. Water-based recreation needs will total 43 million recreation days by 1980 and would cost over $173 million for development and acquisition.

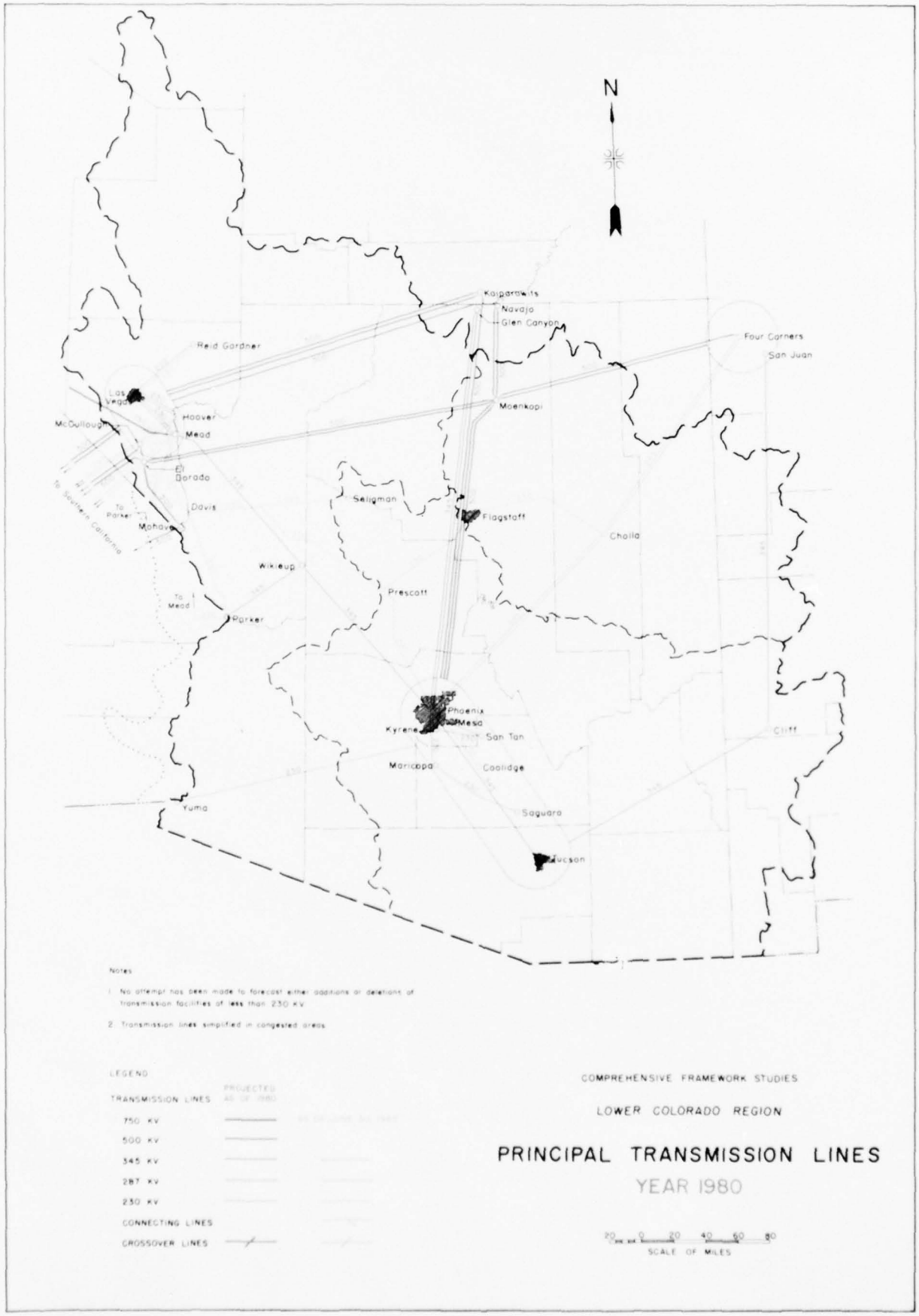
Within existing legal, institutional, physical, and financial constraints, only 35 percent of the needs can be met to satisfy projected recreation needs. Non-Federal entities will have to expand their efforts by two or three times, and Federal involvement, both direct and indirect, will have to be expanded. Urban-oriented recreation developments will particularly need Federal assistance since they account for over 65 percent of the total recreation costs.

Water-based recreation needs can be partially met by facility development and access acquisition at existing lakes and reservoirs in the areas of need. Multipurpose water development programs previously outlined would provide recreation opportunity. Other means of meeting water-based recreation needs include canalside parks, projects using reclaimed water, and single-purpose recreation reservoirs.

Fish and Wildlife

The multipurpose developments expected to be constructed by 1980, including the Alamo, Dixie, and Central Arizona Projects, have the projected potential to provide about 1.2 million man-days of fishing annually.


LOCATION MAP
EXPLANATION
(7) Wildlife Areas (Not to scale)
For additional details of numbered areas, see Appendix XIII — Fish and Wildlife
LOWER
MAIN
STEM
LITTLE
COLORADO
SUBREGION
SUBREGION
GILA
SUBREGION
COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION
DESIGNATED
WILDLIFE AREAS



Notes

1. No attempt has been made to forecast either additions or deletions of transmission facilities of less than 230 KV.
2. Transmission lines simplified in congested areas.

LEGEND

TRANSMISSION LINES — PROJECTED AS OF 1980

- 750 KV
- 500 KV
- 345 KV
- 287 KV
- 230 KV
- CONNECTING LINES
- CROSSOVER LINES

COMPREHENSIVE FRAMEWORK STUDIES

LOWER COLORADO REGION

PRINCIPAL TRANSMISSION LINES

YEAR 1980

20 0 20 40 60 80

SCALE OF MILES

Continued development of the Colorado River and the construction and improvement of fishery developments by state, Indian, and private interests will provide about 2.0 million man-days of fishing annually. Two cold water fish hatcheries are being constructed and will be in production by 1980.

Fishing demand not met by multipurpose reservoirs would be met by primary-purpose fishing lakes of 200 acres or less serving primarily the population centers of Las Vegas, Gallup, Phoenix, and Tucson-Douglas. Approximately one-fourth of the fish habitat would be within the city proper and the remaining three-fourths within 75 miles of the cities.

The program provides for 1,960 acres of primary-purpose fish habitat in the 1966 to 1980 period. Associated fisherman access facilities are provided to assure optimum fishing use of the total habitat expected to be in existence in 1980. The program also provides the equivalent of one cold water and two warm water hatcheries by 1980 to stock the available habitat.

Satisfying future demands for fish and wildlife resources will require that selected areas consisting mostly of large tracts of public land be managed to yield maximum fish and wildlife values. The areas would be managed with emphasis directed to the production of fish and wildlife, with appropriate consideration of compatible and/or complementary uses. Approximately 330,000 acres of existing riparian and wetland habitat would need to be set aside between 1966 and 1980 to be administered principally for wildlife management. Locations of the proposed primary-purpose wildlife areas are shown on the map following page 94.

The early action program includes the construction of access roads into remote areas, fencing, and the development of approximately 1,000 wildlife watering facilities.

Electric Power

By 1980, the Region will need 12.7 million kilowatts of generating capacity including exports of 2.3 million kilowatts--more than twice the 1970 demand of 3.9 million kilowatts. It is anticipated that during this period, the principal sources of additional electric energy will be imports from the Upper Colorado Region which will supply about 4.3 million kilowatts. Generating capacity to be developed within the Region during the 1966-1980 period is estimated to be 0.8 million kilowatts from the Montezuma pumped storage plant to be located near Phoenix and 1.9 million kilowatts from fossil-fueled thermal power plants to be constructed in

southern Nevada. Mohave Power Plant, presently under construction, would supply 1.58 million kilowatts. Principal transmission lines projected for year 1980 are shown on the map following page 94.

CONTINUING PROGRAM, 1981 - 2020

Multipurpose Water Supply

In 1980, an estimated 1.5 million acre-feet water deficiency may be overcome by continued ground-water overdraft and more effective utilization of water supplies. Water withdrawal requirements are projected to increase from the 1980 level of 11.0 million acre-feet to a level of 13.0 million acre-feet in 2020. Depletions will increase from 6.9 to 8.5 million acre-feet in the same period.

The continuing water supply program will provide water to satisfy the increasing demands and to greatly reduce the ground-water overdraft. The only foreseeable method to effectively augment the regional water supply will be by importation from outside the Region. For reasons of efficiency and potential savings in costs, importation studies should include consideration of the needs of the entire Pacific Southwest area.

The first augmentation consideration will be as stated in Title II of the Colorado River Basin Project Act: "The Congress declares that the satisfaction of the requirements of the Mexican Water Treaty from the Colorado River constitutes a national obligation which shall be the first obligation of any water augmentation project planned pursuant to Section 201 of this Act and authorized by the Congress."

Previous reconnaissance studies have indicated that an augmentation of 1.8 million acre-feet would be required to meet the national obligation to Mexico by the year 2000. Other basin augmentation considerations include the rate of development in the Upper Colorado Region, the needs of the southern portion of the California Region, and the dependability of the supply from the Colorado River.

Augmentation proposals in the past have included surface water imports from various areas of surplus outside the Pacific Southwest area desalting of sea water, and precipitation management. Each of these alternatives should be fully explored prior to implementing an augmentation program.

Precipitation management is being studied as a possible source of water for augmentation. The potential magnitude of water quantity that might be provided by this method is unknown, but would probably be

inadequate to meet long-range needs. If large scale modification becomes operational, it could reduce, but not replace, the need for importation.

Importation of surface water from areas of surplus could be one alternative for meeting the water supply deficiency of the Region, as well as that of the remainder of the Pacific Southwest area. Both private and public entities have made various proposals for studies of long-distance water transfers from areas of surplus, such as Canada and the Pacific Northwest. However, legislative constraints and the guidelines for framework studies preclude consideration of this alternative at this time. More specifically, the Secretary of the Interior is prohibited under Title II of the Colorado River Basin Project Act of September 30, 1968, for a period of 10 years from the date of the Act, from undertaking studies of any plan for the importation of water into the Colorado River Basin from any natural river drainage basin lying outside the States of Arizona, California, Colorado, New Mexico, and those portions of Nevada, Utah, and Wyoming that are outside the natural drainage basin of the Colorado River.

The desalting of sea water remains as the one available source for large scale water importation which may be considered in the Type I studies and for which general cost information is available. Therefore, desalting was considered the source of additional water for the Region and the basis for estimating the general magnitude of costs presented herein. A major factor in considering importation on a regional basis is that the water needs of the entire Pacific Southwest area should be coordinated into a comprehensive plan of which the Lower Colorado Region's augmentation needs would be an integral part. Exploration should also be made of the possibilities of exchanging desalted water for Colorado River water presently being conveyed to the coastal areas of southern California, thereby releasing Colorado River water for use within the basin. This would offer only limited augmentation as the quantities to be diverted after CAP is operational would not exceed 550,000 acre-feet. Future studies should be directed also toward the siting of major desalting facilities.

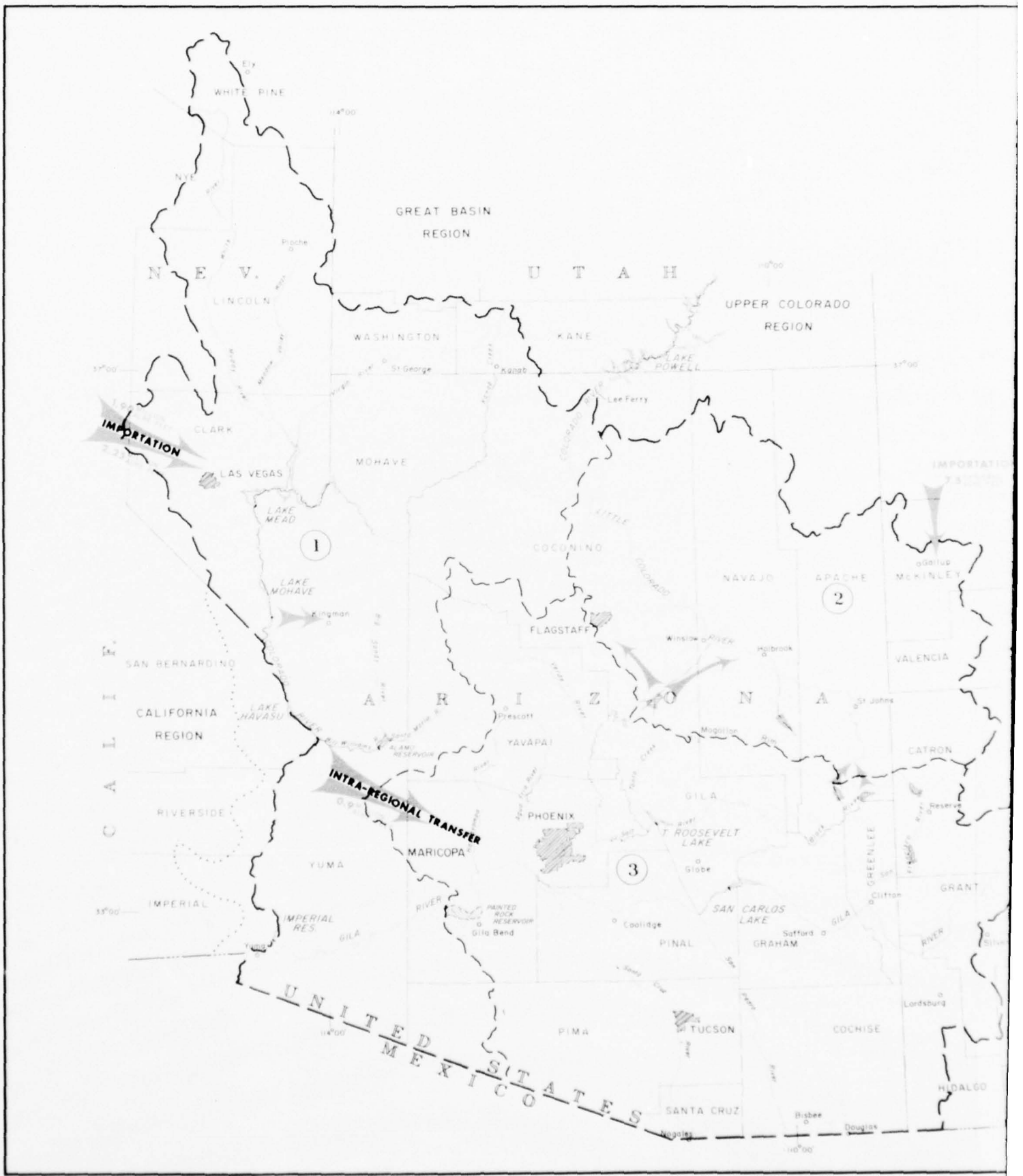
For the purpose of the Type I studies, the following assumptions were made: (1) that desalting facilities would be located along the southern California coast; (2) that desalted water would be conveyed to Lake Mead: (3) that the 1906 to 1965 period of record defines the quantity of Colorado River water available; (4) that the initial importation to relieve the basin states of the Mexican Water Treaty burden would be a national obligation and would be implemented near the end of the 1981 to 2000 time frame; and (5) that augmentation water would include sufficient quantities so that ground-water overdraft would be greatly reduced by 2020.

The framework program provides for the importation, prior to the year 2000, of 2.25 million acre-feet of desalted sea water to the Lower Colorado Region, including 1.80 million acre-feet of water to satisfy the national obligation to Mexico and 0.45 million acre-feet as a regional program. Lake Mead would provide seasonal regulatory storage for the imported water, thus allowing maximum use of the facilities, whereas alternative downstream reservoirs do not provide adequate storage. The water quality benefits achieved through mixing high quality desalted water with Colorado River water would be extensive, and by use of Lake Mead for storage, a portion of the increased costs could be recovered through increased power generation at Hoover and Davis Dams.

If the initial water importation were in operation at year 2000, there would remain a regional annual water deficiency of about 0.44 million acre-feet which would increase to about 2.1 million acre-feet annually by 2020. It is recommended that between 2000 and 2020, additional importation facilities provide about 1.9 million acre-feet annually, thereby reducing the Region's annual deficiency by year 2020 to 0.17 million acre-feet. It is expected that some ground-water overdraft will continue throughout the study period, particularly in outlying basins remote from augmentation service areas.

Additional facilities would be included to convey the successive stages of imported water from the Colorado River to the areas of need. Terminal regulatory reservoirs having a combined storage capacity of about 600,000 acre-feet would be required in the vicinities of the major demand centers. Such reservoirs also would provide about 14,000 surface acres for recreation opportunities and for fish and wildlife uses.

Other facilities providing suitable water for multipurpose uses include tertiary treatment of 680,000 acre-feet annually of conventionally treated municipal and industrial waste water for reuse in Clark County, Nevada; and in Maricopa and Pima Counties, Arizona, the treatment of an additional 0.9 million acres of forest lands would increase annual water yield by 150,000 acre-feet. Augmentation of water supplies in the central Arizona area will provide, through water exchanges, additional water for use in upstream areas for municipal, industrial, and mineral production needs, as well as for alleviating irrigation water deficiencies. Reservoir storage totaling 0.4 million acre-feet is provided to regulate flows for use in the upstream areas, largely in the Gila Subregion. See the following map, "Potential Water Resource Development Continuing Program, 1981-2020," for water resource development.


GREAT BASIN
REGION
UPPER COLORADO
REGION
CALIFORNIA
REGION
NEV.
UTAH
ARIZONA
WHITE PINE
LINCOLN
WASHINGTON
KANE
CLARK
MOHAVE
COCONINO
NAVAJO
APACHE
MCKINLEY
YAVAPAI
YUMA
LA PAZ
RIVERSIDE
SAN BERNARDINO
IMPERIAL
MARICOPA
PINAL
GILA
GRAHAM
GREENLEE
GRANT
CATRON
VALENCIA
PIMA
COCHISE
SANTA CRUZ
HIDALGO
PINAL
IMPORTATION
INTRA-REGIONAL TRANSFER
LAKE POWELL
LAKE MEAD
LAKE MOHAVE
LAKE HAVASU
SAN CARLOS LAKE
LAS VEGAS
FLAGSTAFF
PHOENIX
TUCSON
YUMA
Ely
Pioche
St George
Kanab
Lee Ferry
Kingman
Prescott
Winslow
Holbrook
Gallup
Magollon
St Johns
Globe
Coolidge
Safford
Clifton
Lordsburg
Bisbee
Douglas
Nogales
Gila Bend
Yuma
1
2
3
UNITED STATES
MEXICO

INDEX MAP

UPPER COLORADO REGION

LAKE POWELL

Lee Ferry

IMPORTATION

NAVAJO

APACHE

GALLUP

MCKINLEY

2

VALENCIA

Winslow

Holbrook

St Johns

Magollon

CATRON

GILA

Reserve

T ROOSEVELT LAKE

3

Globe

GRANT

Clifton

SAN CARLOS LAKE

Coolidge

Safford

GRAHAM

PINAL

Silver City

RIO GRANDE REGION

Lordsburg

TUCSON

COCHISE

HIDALGO

SANTA CRUZ

Bisbee

Douglas

Nogales

EXPLANATION

- Lower Colorado Region boundary
- Subregion boundary
- (1) Lower Main Stem
- (2) Little Colorado
- (3) Gila
- Lower Colorado Basin boundary
- Existing dam and reservoir
- Existing dam and intermittent lake
- Potential Development 1981-2000
- Potential Development 2000-2020

COMPREHENSIVE FRAMEWORK STUDY
LOWER COLORADO REGION

POTENTIAL WATER RESOURCE DEVELOPMENT

CONTINUING PROGRAM
1981-2020

MAP NO. 1019-300-2

50 0 50 100 200

SCALE OF MILES

NOVEMBER 1970

2

Water Quality

As water use in the Upper Colorado Region increases, less water and poorer quality water enter the Lower Colorado Region. Specific salinity control programs are proposed for the Las Vegas and Yuma areas, for Blue Spring in the mouth of the Little Colorado River, and for LaVerkin Springs in southwestern Utah. These programs would be elements in a combined Colorado River Basin Salinity Control Program recommended for implementation in both the Upper and Lower Colorado Regions. While the elements in the Basinwide program located within the Lower Colorado Region would provide only a limited degree of salinity improvement, implementation of the complete program would be highly significant, removing about 25 percent of the dissolved salts in the river at Lake Mead in the year 2000.

Large-scale importation of high quality water also would be effective in reducing salinity of Colorado River water; however, the proposed importation of water is intended to satisfy depletion requirements only and special legislation would be required to authorize importation of water primarily for quality control.

The proposed water quality program includes several waste water treatment plants and reuse facilities at or near the places of use. Notable among these is a 150 million gallons per day nuclear desalting plant near Buckeye, Arizona, to treat irrigation return flow for reuse. A desalting plant is also considered essential to the treatment of effluents from the Las Vegas area.

In addition, the land treatment and management program described in the following section will materially benefit the water quality of the Region's surface water supply.

Continued studies are proposed for the identification and solution to physical, engineering, legal, and institutional considerations necessary to the implementation of a sound water quality program for the Region and the entire Southwest.

Land Treatment and Management

Increased pressure on the land resources, inherent in the expanding needs and demands of the Region's population, will necessitate continuation of the early action land treatment and management program on 43.3 million acres. In most cases, the same acre may require treatment more than once during the 40-year period because of development of improved methods, or because of the limited life of the measure or practice installed.

Cropland--The continuing land treatment and management program consists primarily of measures for erosion, sediment, and runoff control to be installed on about 420,000 acres of cropland during the period 1981 to 2020.

Rangeland--Measures for control of erosion, wildfire, sediment, and damaging runoff, and for improvement of forage production, are included for about 35 million acres of rangeland.

Forest Land--Programs for meeting the demands for forest resources and uses by 2020 will require that about 40 percent of the forest resource potential be developed. This is equivalent to the development of about 7.6 million acres of forest lands during the period from 1981 to 2020. Treatment of forest land to increase water yield by about 150,000 acre-feet annually through vegetative management and to improve timber and forage production is planned.

Urban and Other--The program provides for installation of land treatment and management measures on about 510,000 acres of urban and other lands for erosion, sediment, and runoff control during the 1980 to 2020 period.

Flood Control

The continuing flood control program includes impoundments totaling more than 1.2 million acre-feet of storage, 535 miles of channel improvements, and 165 miles of levees, land treatment protection on 545,000 acres, and nonstructural measures. Average annual benefits from the recommended flood control program by 2020 would average about $242 million--a reduction in flood damage of approximately 78 percent. It is not physically or economically feasible to prevent all flood damage due to the complexity of weather and topographic features, and the dispersed nature of the damageable values. Remaining damages at the end of the study period would total $68 million annually. The 1966-2020 Flood Control Program is shown on the map following page 92.

Municipal and Industrial Water

The program to meet long-range future needs of the Region for municipal and industrial water includes conservation of existing supplies and augmentation of existing supplies by importation, transfers from other uses, ground-water development, desalination of brackish supplies, and water reuse facilities.

Municipal and industrial water withdrawal requirements are expected to increase by about 2 million acre-feet between 1981 and 2020.

It is estimated that transfer of farmland to urban and industrial uses will result in some water being transferred from agricultural to municipal uses. The major municipal water development would be participation in a regional water importation program. Completion of the Southern Nevada Water Project facilities will meet the water needs of Las Vegas until about year 2000. A 100 million gallons per day desalination plant for treatment of municipal wastes is scheduled for Clark County in the 1981 to 2000 time frame, after which a new supply will be needed. Desalting facilities having capacities totaling 123 million gallons per day are included in the program to treat brackish ground water for municipal uses in 9 communities, most of which are not identified. An import of 7,500 acre-feet from the San Juan River is included to supply water for municipal uses in Gallup, New Mexico. Multipurpose regulatory storage facilities in upstream areas would meet the needs of many of the smaller communities. Continued development of ground-water supplies, with desalting where necessary, will meet the needs of most of the other small communities.

Irrigation and Drainage

It is assumed that rehabilitation of existing irrigation conveyance systems, where required, will have been completed by 1980. It is estimated that during the period 1981 to 2020, about 176,000 acres of presently irrigated lands will be occupied by urban development. During this period, a net gain of 124,000 acres in irrigated area is predicted. To effectively utilize the imported water and to provide water to new lands, additional conveyance systems to serve about 730,000 acres will be provided. Portions of these lands are now irrigated exclusively from ground water.

The continuing program for installation of measures for irrigation water management on 1.6 million acres is provided to achieve the projected efficiency of onfarm irrigation water use and to maintain the productive capacity of the land. With the addition of imported water supplies and projected increases in irrigated lands after 1981, the plan provides for new drainage facilities to serve an additional 120,000 acres by year 2020.

Recreation

The continuing (1981 to 2020) recreation program will require $858 million for the acquisition of 46,000 acres of land to satisfy projected needs for 234 million recreation days.

Multipurpose reservoirs in the Gila Subregion would make available about 39,000 surface acres of water for recreational use. There would remain an unmet need of almost 45,000 acres of water by the year 2020 to satisfy boating opportunity. Canalside parks constructed in conjunction with the Arizona Aqueduct would partially meet recreation needs.

The majority of recreation needs would largely remain unmet without modification of existing legal, institutional, and financial arrangements. These unmet needs would amount to 293 million recreation days and $1,129 million for the period 1981-2020.

Fish and Wildlife

The multipurpose developments presently being considered for construction and improvement for the period 1981 to 2020 have the potential to provide approximately 1.0 million man-days of fishing, of which about 60 percent would be expended within 75 miles of the major urban centers. Small primary-purpose impoundments having a total area of 32,440 acres are included in the program to meet the fishing demand during the 1981 to 2020 period.

Program-associated fishermen access facilities to assure optimum fishing use are provided in the program. Also, to stock the available habitat and that projected to meet fishing demands, the program provides for one cold water hatchery every 8 to 10 years and one warm water hatchery every 6 to 8 years.

The continuing wildlife program for the Lower Colorado Region identifies 11.5 million acres of public lands as needing more intensive management to yield maximum wildlife values. The areas would be managed with emphasis directed to the production of fish and wildlife, with appropriate consideration of compatible and/or complementary uses. The identified areas include some of the more valuable wildlife habitat areas in the Region, plus other areas which have a high development potential due to their location within reasonable-use distance of the major metropolitan areas. The program also provides for accelerated development and improved wildlife production on other public lands throughout the Region having wildlife values.

This continuing program provides for the construction of needed access roads, fencing, and about 48,000 wildlife watering devices.

Electric Power

Electric power requirements are projected to increase to 108 million kilowatts during the 1981 to 2020 period. The development program to meet these demands consists of transmission facilities for imports, fossil-fuel thermal plants, nuclear-fuel thermal plants, and pumped storage hydroplants.

Further studies will be needed to determine where the power facilities should be located. Factors to be studied will include the costs of conveying cooling water to water-deficient areas versus the cost of

transmitting energy longer distances, the hazards of thermal and nuclear pollution, conflicts with preservation of natural or scenic areas, and other environmental factors. Consideration will need to be given to the use of dry-type cooling in lieu of water cooling. The magnitude of increased electric power production needed will require close attention to design requirements for air and water pollution control measures. Principal transmission lines to be required in year 2000 and year 2020 are shown on maps following page 104.

ALTERNATIVE PROGRAM CONSIDERATIONS

Water Conservation and Reclamation

Many alternative means of conservation and reclamation of the Region's water supplies were considered during the course of the studies and those that appeared reasonable were incorporated into the program. Major alternatives considered are as follows:

1. Increased irrigation efficiency--Provision was made for the rehabilitation of existing conveyance systems to reduce seepage and other losses. Improved irrigation practices would increase onfarm efficiencies from the present 60 percent average to 75 percent by 2020. Soil conditions and leaching requirements would limit efficiencies to about the 75 percent projected.

2. Water reclamation and reuse--The regional water supply utilized in the framework program assumes reuse of all water. Provisions for the reclamation of water through treatment and/or recharge to underground reservoirs are included in the program.

3. Phreatophyte removal and control--The removal and control of some riparian vegetation are included in the program for the annual salvage of 300,000 acre-feet of water and for channel maintenance. Wildlife considerations materially limited the extent of this salvage program.

4. Increased water yield--Vegetative management practices are included in the program to increase annual runoff by 180,000 acre-feet by 2020. Wildlife considerations also limited the extent of this program.

5. Reservoir evaporation suppression--The effectiveness of and benefits to be derived through evaporation reduction measures is the subject of considerable controversy. Further research is needed before this program can be evaluated.

6. Desalting of brackish water--The desalting of brackish water is included in the framework program where this alternative suits local conditions.

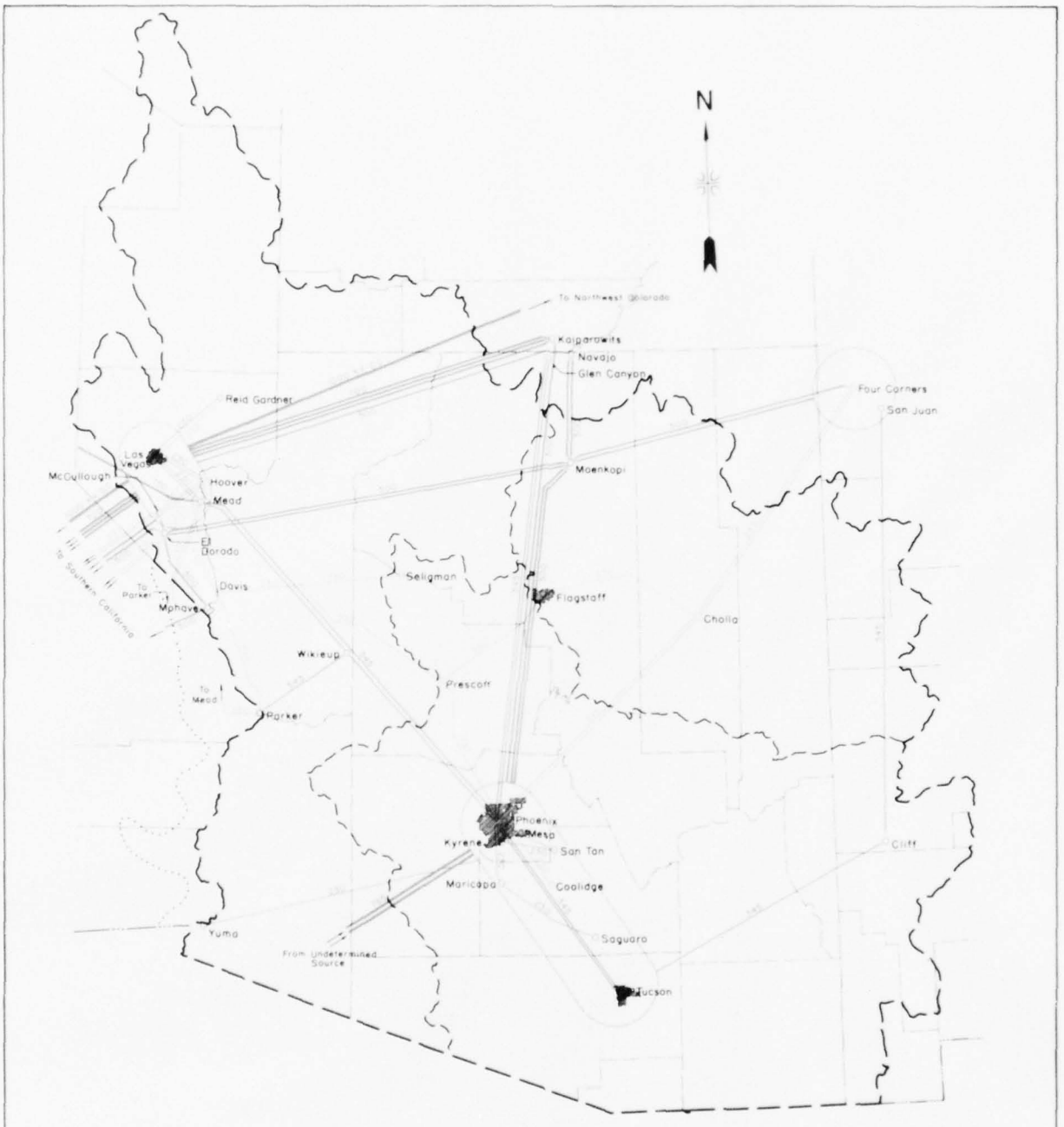
7. Weather modification--Additional research is needed to determine the potential of this program for the Lower Colorado Region. A successful program could reduce, but not replace, importation requirements of the Region.

8. Reduction in municipal uses--Though not incorporated into the framework program, efforts should be made to reduce municipal water consumption. This program may be difficult to accomplish in this desert environment and the potential savings may be limited.

9. Intraregional water transfers--The transfer of water from areas having surplus supplies to water deficient areas within the Lower Colorado Region was utilized to the maximum possible extent.

10. Interregional water transfers--Guidelines for the Framework Studies precluded consideration of transbasin diversions of water supplies from outside the Pacific Southwest area.

11. Desalting of ocean water--Desalting of ocean water and conveyance to the Lower Colorado Region was considered as a primary source of augmentation.



LEGEND

TRANSMISSION LINES

	PROJECTED AS OF 2000	AS OF JUNE 30, 1965
1000 KV D.C.		
765 KV		
700 KV		
500 KV		
345 KV		
287 KV		
230 KV		
CONNECTING LINES		
CROSSOVER LINES		

Notes:

1. No attempt has been made to forecast either additions or deletions of transmission facilities of less than 230 KV.
2. Transmission lines simplified in congested areas.

COMPREHENSIVE FRAMEWORK STUDIES

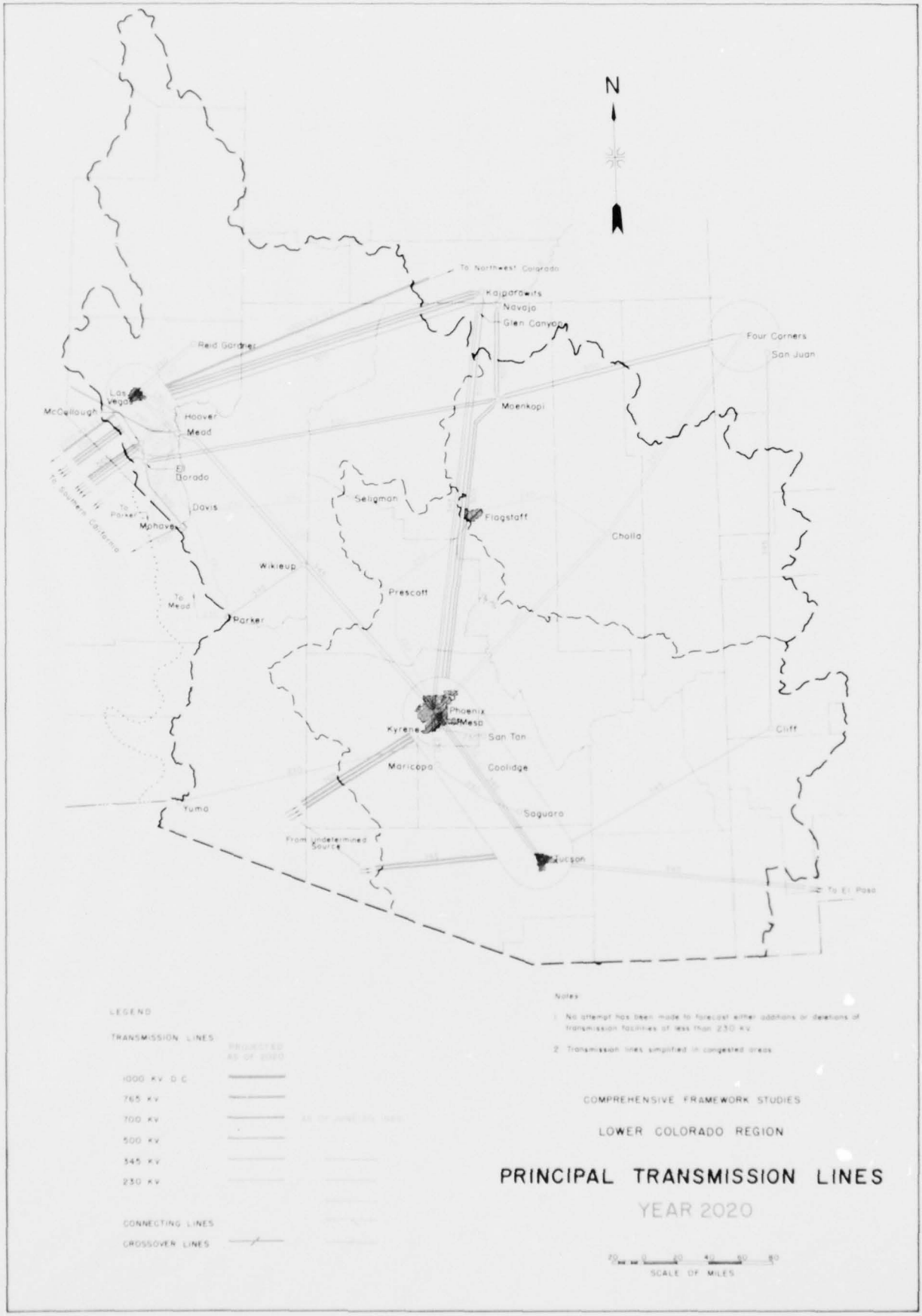
LOWER COLORADO REGION

PRINCIPAL TRANSMISSION LINES

YEAR 2000

20 0 20 40 60 80

SCALE OF MILES



LEGEND

TRANSMISSION LINES

	PROJECTED AS OF 2020	AS OF JUNE 30, 1965
1000 KV D.C.		
765 KV		
700 KV		
500 KV		
345 KV		
230 KV		

CONNECTING LINES

CROSSOVER LINES

Notes

1. No attempt has been made to forecast either additions or deletions of transmission facilities of less than 230 KV.
2. Transmission lines simplified in congested areas.

COMPREHENSIVE FRAMEWORK STUDIES

LOWER COLORADO REGION

PRINCIPAL TRANSMISSION LINES

YEAR 2020

SCALE OF MILES

PROGRAM EVALUATION

CHAPTER H - PROGRAM EVALUATION

The comprehensive framework program responds as nearly as practicable to the projected needs of the social and economic activities of the Region. However, for some program activities, it is not practicable to satisfy all needs. Some water-related activities will require further studies to more clearly define the requirements, potential programs to satisfy requirements, and the limiting effects of available resources.

Water Supply

All visualized, reasonable means of water conservation, salvage, and reclamation, as well as maximum utilization of the Region's surface- and ground-water supplies for which there are tangible means of evaluation and which are reconcilable from an environmental aspect, have been considered in the development of the framework program. Where other recognized possibilities exist, further study has been recommended to develop adequate information to evaluate the potential. With the incorporation of all known, practicable water conservation means and development of water resources within the Region, it appears that there will still be a significant regional water deficiency that can be met only through importation from outside the Region.

At this time, it is difficult to place a finite value on the water deficiency because of the large number of variables involved and the lack of sufficient data. Therefore, using the data available, it was necessary to make numerous basic assumptions in order to estimate the general magnitude of facilities and costs for a program to satisfy, as nearly as practicable, projected regional needs.

One of the major assumptions was that the average annual virgin flow of the Colorado River was represented by the 1906 to 1965 period of record. Although the 1906 to 1965 period was selected as representative of the average annual virgin flow of the Colorado River, use of shorter, more recent periods of record would have indicated greater water deficiencies. Because of the uncertain nature of long-term projections of water requirements, they should not be regarded as exact or final. Such projections do, however, establish the order of magnitude of future water supply deficiencies and the scope of required water supply programs. Periodic assessments of the water situation will be necessary to appropriately gauge future program response.

The fact that large bodies of ground water exist and are not being utilized is evidence of the many problems and uncertainties connected with developing this water for beneficial use. The practicability of

development and utilization of the greater portion of these ground-water reserves involves many factors. Among the problems encountered are: water of poor quality; deterioration of quality with depth, or with recirculation of used water; low yields from wells in some of the aquifers; remoteness of new aquifers from areas where excessive pumping has caused land subsidence; the limited period during which a large overdraft can be maintained; and, the legal rights of overlying land owners. Many of these problems have not yet been adequately evaluated and should be given top priority in future studies.

The Region's present ground-water overdraft will increase considerably by 1990, the earliest probable date that an importation program could be in effect. In the meantime, as the ground-water level declines, the price of pumped water will increase. Under such a competitive situation, water utilization will tend to shift toward uses offering the highest economic return, unless constrained by legal and institutional factors.

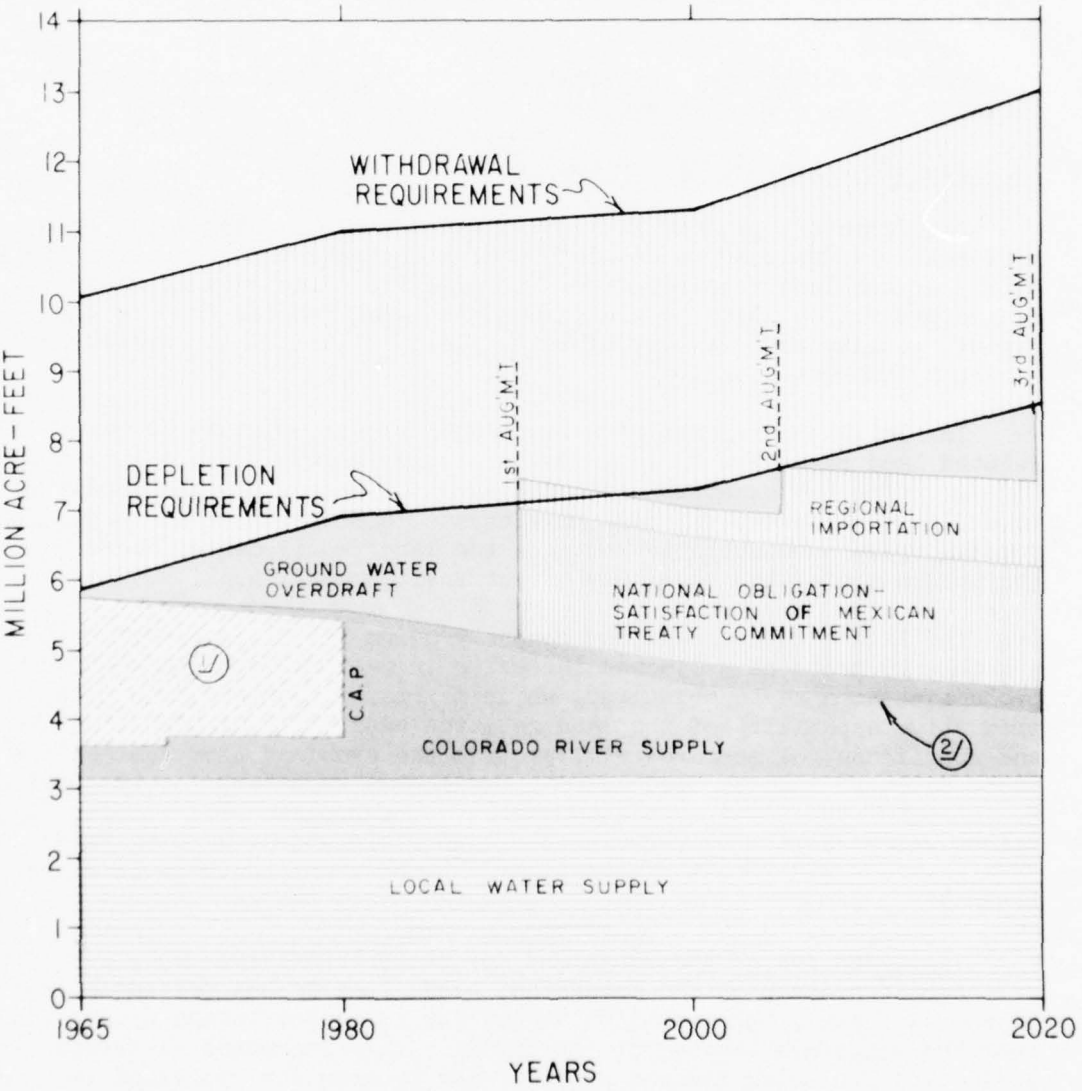
Some ground-water overdraft is expected to continue beyond year 2020, mostly in the Gila Subregion. This overdraft would occur largely as a result of agricultural development in the more remote ground-water basins; mineral developments, where surface supplies are unavailable; and water supply developments, in minor amounts, for the smaller communities remote from surface-water sources. It is not likely that ground-water overdraft would be entirely eliminated even in import water service areas where a combination surface-ground-import-water supply is utilized. The annual rate of ground-water overdraft after 2020 is largely conjectural. Figure 17 illustrates the regional water requirement and supply picture for 1965 through 2020.

Water Quality

The maintenance of an acceptable level of water quality is particularly critical and complex in the Lower Colorado Region where maximum water utilization must be obtained by recycling available supplies. Colorado River water released to Mexico must continue to be regulated to closely approximate the quantities necessary to meet the Mexican Treaty commitment, while, at the same time, efforts must be continued to maintain quality. The high cost of imported water will probably dictate the continuation of an exceptionally high water-use efficiency with little or no allowance for transportation of salts or waste loads from the Region. A Colorado River Basin Salinity Improvement Program, coupled with an importation of high quality water to the Region, would stabilize the water quality of the Colorado River water near the present level.

Negligible outflow from the Gila Subregion is expected to continue. The area having the most critical unmet need for water quality control

FIGURE 17
PROJECTED WATER REQUIREMENTS AND SUPPLY



1 AVAILABILITY OF COLORADO RIVER WATER AFFECTED BY LACK OF DIVERSION FACILITIES. REQUIREMENTS ARE MET BY GROUND WATER OVERDRAFT

2 WITHIN REGION AUGMENTATION

will probably continue to be in the Gila Subregion where recycling of water results in the progressive concentration of salts that ultimately accumulate in the ground-water reservoir.

Further studies are needed to determine the extent and rate of water quality degradation to be expected under various operating conditions, to examine the alternative solutions to the problems, and to evaluate the consequences of various alternative levels of water quality control measures.

Table 9 illustrates the effects of water quality control measures included in the framework program.

Land Use and Watershed Management

The framework program includes a variety of structural and management measures designed to maintain and/or increase the productive capability of the land resource base, increase the efficiency of water use, reduce production costs, decrease damaging peak runoff, improve the timing, quality and quantity of water yield, stabilize streamflow, and decrease sediment yield.

The land requirements were based upon the translation of water and related land resources to satisfy short- and long-term needs within the Region. With the exception of those uses not dependent upon productive capability, failure to install an adequate land treatment and management program would substantially increase the land requirements, increase production costs, and adversely affect environmental quality.

The land treatment and management program for cropland will make it possible to meet the projected increases in demands for food and fiber production at a reasonable cost, while maintaining or improving the productive capability of the land resource base. The erosion, sediment, and runoff control measures will protect the cropland from damage from these sources, and the associated programs are necessary for the implementation of the total cropland program. The program will beneficially affect water quality by reducing sediment yield and by keeping farm chemicals out of the water courses and on the cropland where they are needed.

Increased use of the rangeland for recreational and other purposes will create protection and management needs that do not presently exist. At the same time, there will be a need for increased forage production from the rangeland because of the significantly increased livestock production projected for the Region. The program for rangeland is designed to protect the land base while satisfying as much of these demands as possible.

Table 9
Projected Concentrations of Total Dissolved Solids
in the Lower Colorado River
(mg/l)

Location	1965	1980		2000		2020		Percent Increase 1965-2020	
		Without Program	With Program	Without Program	With Program	Without Program	With Program	Without Program	With Program
Colorado River									
at Lee Ferry, Arizona	586	650	560	760	580	820	630	40	8
below Hoover Dam	734	950	860	1,010	810	1,050	850	43	16
below Parker Dam	726	980	870	1,140	870	1,150	880	58	21
at Imperial Dam	839	1,260	1,100	1,290	980	1,350	1,030	61	23

The program for proper use and management of forest land will have the effect of reducing the cost of producing forest resources, will result in effective multiple use of forest areas, will correct much of the current damages to the forest resource, and prevent further degradation of the forest environment.

The program for water yield increase involves only forest land and will, if properly carried out, improve the habitat for most wildlife, increase domestic livestock forage, and give added protection to the soil, thereby decreasing sediment production.

Total average annual sediment yield for the Region, considering the projected yield with no program, would be reduced by about 8,500 acre-feet by 2020 with the going program. The recommended program would further reduce the total yield by about 11,000 acre-feet per year. This would significantly decrease downstream sediment damages, including deposition on agricultural lands, in reservoirs, and in urban areas. The program would beneficially affect water quality by reducing sediment content.

Since total reduction of erosion damages is neither physically nor economically feasible, erosion control structures were considered for only the most critical areas where either onsite or downstream damages are significant. Erosion damages are projected to increase from $6.7 million in 1965 to $24 million in 2020 without additional protection. With the outlined program, it is estimated the 2020 damage would be reduced to about $7 million. The program would be effective in reduction of land loss from gully and streambank erosion; give protection to a major portion of the land presently being damaged through loss in productivity, by sheet, scour, and rilling; and provide protection to improvements, equipment, and public facilities.

Wildfire damages are projected to increase from $5.7 million in 1965 to $20.0 million in 2020. The accelerated recommended program would reduce the 2020 damages to about $12.0 million. Provision is made to give protection to the expanding developments scattered throughout the forest and rangelands of the Region.

Flood Control

Flood damages have increased and will continue to increase due to recent and projected future population increases and continued economic development in the flood plains. A flood control program of structural and nonstructural measures is desirable for the protection of every individual and every parcel of land or property that is potentially endangered by floods in the Region. In addition to general storms, localized but often high intensity storms cause flash-flood type of runoff unpredictably scattered throughout the Region.

There will be remaining damages after implementation of the program because it is impracticable to provide structural measures against all floods at all locations or to deny flood plain use for all purposes.

The regional framework flood control program is directed mainly toward the collective needs in areas where damageable values are of sufficient scope to justify the costs of projects. Figure 18 shows the effects of the flood control program.

Irrigation and Drainage

The framework program, including a modest net increase of 298,000 acres of irrigation development and drainage measures on 188,000 acres, will satisfy essentially 100 percent of the projected irrigation and drainage needs. The satisfaction of these needs will assure the regional capability of meeting the projected requirements for agricultural production.

The framework program for irrigation development will utilize only a small fraction of the Region's 36 million acres of potentially irrigable land. This is primarily because of the paucity of local water supplies available for irrigation and the high cost of importing water for new irrigation development. In addition, economic constraints are indirectly imposed on large-scaled irrigation development because the Region's allotted share of OBE-ERS projected national agricultural production requirements justifies only modest additions to the present level of irrigation development.

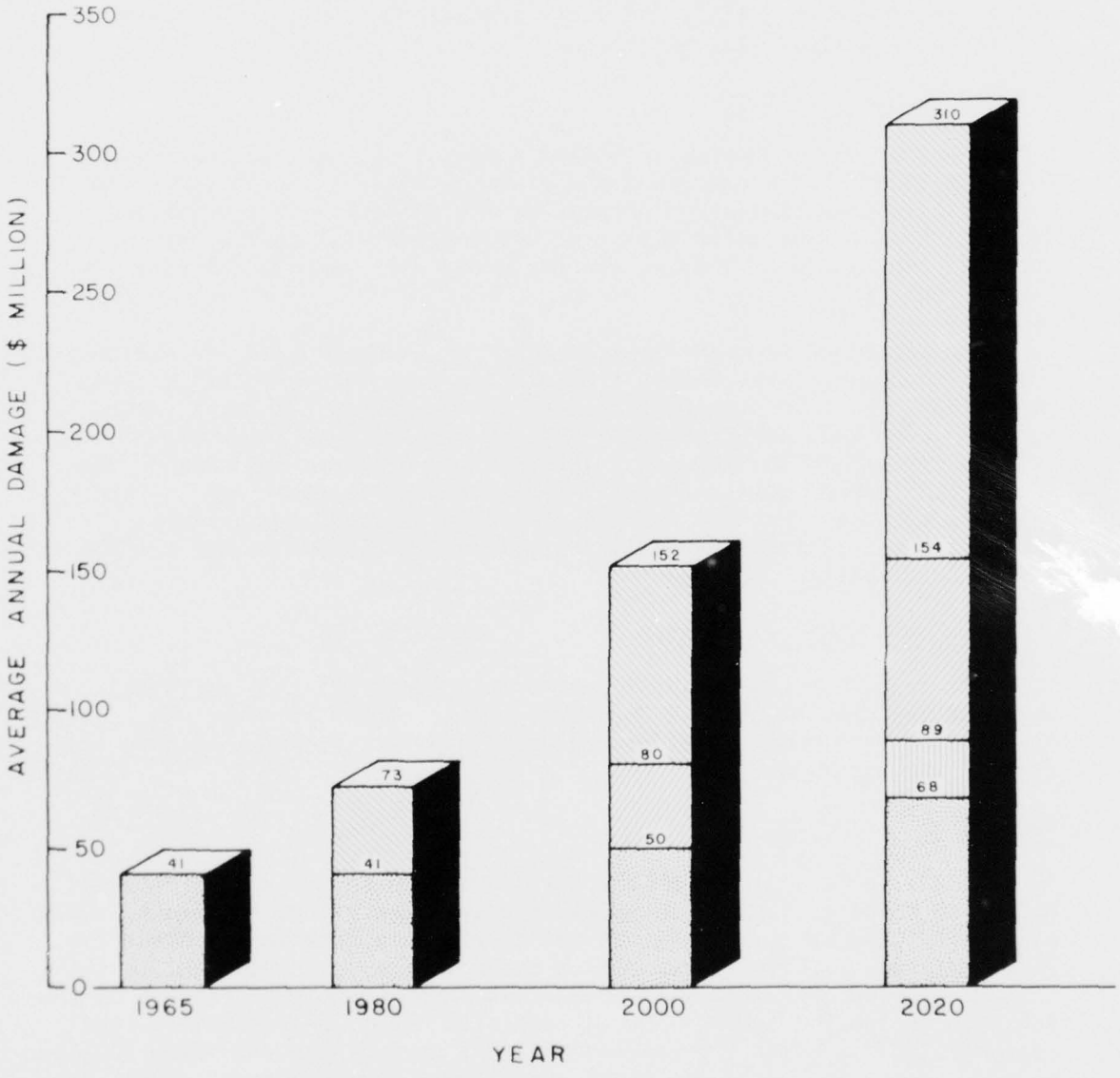
Municipal and Industrial Water

The framework program provides for the municipal and industrial needs of the urban centers. Further study is needed, however, to identify the needs of the small rural communities, many of which do not have adequate water supplies.

Recreation

If the projected 2020 demand for recreation in the Lower Colorado Region is to be satisfied, the present recreation resource capacity would need to be quadrupled. But it is not feasible to develop a program that would meet the particular recreation desires of every individual in the Region. The program presented would meet approximately 42 percent of the Region's recreation needs. New or modified legal, institutional, and financial arrangements are necessary if any part of the remaining 58 percent of recreation needs are to be satisfied. Physical constraints, such as the shortage of surface area of water, preclude complete satisfaction of recreation needs. The distribution of population relative to resources

FIGURE 18
EFFECTS OF FLOOD CONTROL PROGRAM
1965 - 2020



creates part of the problem. Alternative recreation opportunities must be provided if needs are to be met.

The recreation program does not provide specific plans for facility location, but rather provides the mechanisms through which these specific plans could be developed.

Fish and Wildlife

The fish and wildlife program is formulated on the basic assumption that the 1965 resource base provides a sound foundation on which to formulate a plan to satisfy all projected fish- and wildlife-oriented recreational needs.

The plans and projections involving other phases of the framework program have a significant effect upon the fish and wildlife resource base. Features are included that both benefit and detract from the basic fish and wildlife resource. They may result in a species composition change or a use-type change, such as a reservoir providing a fishery at the expense of wildlife production. The ultimate need is for an expanded, well balanced plan for the enhancement of fish and wildlife resources, especially wildlife, to meet future demands.

To determine the viability of the fish and wildlife program within the comprehensive framework program would require extremely detailed information concerning the environmental conditions of the areas to be developed. A more detailed analysis of the regional comprehensive program may indicate the need for a larger, more positive role for the fish and wildlife program.

Electric Power

Projections of electric power requirements, as provided by the Electric Power Work Group, and those developed in the course of economic input-output model studies are at variance. The economic studies indicate electric power requirements in the order of one-third of those projected in the Electric Power Appendix. Such a difference would result in about 0.4 million acre-feet less water depletion in the Region, assuming a proportionate balance between energy generation within the Region and import-exports. This represents about 18 percent of the total regional increase in water depletion requirements for all uses during the 1966 to 2020 period. It must be remembered, however, that projections of electric power requirements beyond 1980 are extremely difficult to estimate, especially since a major influence is the increased per capita use, and the trend toward substitution of electricity for other forms of energy. Though there is considerable variance, and the differences have not been resolved, those projections contained in the Electric Power Appendix have been utilized in the framework program.

Conflicts

In developing the framework program, attempts were made to attain maximum multiple use of water and related resources, while enhancing the quality of life. However, in the Lower Colorado Region, the renewable water resource is inadequate to meet the existing and expected future demands. Conflicts among uses of water and related land resources exist and are expected to continue. Compromises are necessary in formulating resource development plans.

Changing technologies, needs of people, and resource situations will, to a large extent, determine the management direction and the coordination needed to foster optimum resource development. There is a limit to the amount of goods and services that the land and water resource base can yield, even with anticipated technological advances. As the demands increase for more food and fiber, goods and services, recreational opportunities, open and green space, less pollution, and better environmental quality, sound management objectives will increasingly need to be recognized and emphasized. This will require the management of all the resources for the greatest benefit of all the people.

Conflicts are inevitable in the competition for land and water resource development. The growing demands give rise to an important policy issue: natural resource use and conservation on the one hand versus the rapidly increasing demands of an affluent society on the other. All land and water resource development programs should minimize conflicts among the various preservation, conservation, development, and land-use policies. The program should provide for the coordination of all resource use and activities.

The principle of "multiple use" has come to be regarded important to good resource management. "Multiple use" is a system of planning and applying management on specific areas which attempts to achieve the protection, development, and use of its various resources so that they may be utilized in the best combination, on a sustaining basis, to meet the needs of the people. Periodic adjustments will be required.

Environmental considerations are involved in many of the more prominent conflicts as exemplified in the following:

1. Stream reaches that would be inundated by proposed water storage or flood control reservoirs often contain prime wildlife habitat. The fish and wildlife programs are aimed at preserving this type of habitat. However, most reservoirs with permanent pools will provide a fishery which would offset some losses.

2. Phreatophyte removal and control along streams, drainage of wetlands, and stream channel improvements reduce riparian vegetation and, in some cases, may affect esthetics and the wildlife resource base.

3. Alteration of particular types of native vegetation is sometimes necessary for treatment of land for increased livestock forage, erosion and sediment control, and increased water yield. This tends to be detrimental to some wildlife species while benefiting others.

4. Reservoirs may occupy reaches of potential wild, scenic, and recreation rivers, and parts of designated or potential wilderness areas. It will be necessary to study and determine the need for reaches of streams to be designated as wild and scenic rivers.

5. Reservoirs, as well as many other improvements, could inundate or obliterate archeologic, cultural, or historic sites. These sites contain the key to the heritage of the past and their loss would be irretrievable.

6. Developments such as highways, transmission lines, and urban development alter the natural environment and tend to reduce the resource base of the Region.

7. Despite advances in antipollution design and technology, thermal electric power plants cause some pollution of the environment and the growing antipathy toward such plants may become a deterrent to installation.

8. Competition among uses of available water will be one of the strongest conflicts in years ahead, particularly in the absence of adequate regional water supply augmentation. Implementation of all programs requiring a water supply would be difficult and, in some cases, impossible.

9. Urban expansion is predicted to encroach on prime agricultural land. Irrigated agriculture may be forced to develop less suitable land in order to maintain a stable agricultural economy.

10. Fish and wildlife interests have indicated that large acreages of land need to be managed primarily for wildlife. Other interests have indicated that some of these same areas need to be managed on a multiuse basis which may conflict with primary fish and wildlife uses.

These, of course, are only a few of the issues which must be resolved. When segments of the program and alternatives are sufficiently detailed, choices can be made. Many alternatives may emerge from the recommended future studies. Improved technology may introduce new alternatives and changing economic conditions may influence future resource development.

It is important that a concerted effort be made in the early action period to resolve as many of these conflicts as possible.

Summary

Table 10 is a summary of projected requirements, program response, and percent response for the major sectors of social and economic activities in the Region.

Table 10
FRAMEWORK PROGRAM RESPONSE TO PROJECTED RE
Lower Colorado Region

Major Program Elements	Unit	1966-1980 Projected Require-ments	Program Response	Percent Response	Remaining Needs	Project Require ments
Regional Water Supply 1/	1,000 Acre-Feet	14,895	13,410	90	1,485	14,90
Municipal and Industrial Water Supply Development	1,000 Acre-Feet	837	837	100	--	1,67
Flood Damage Prevention	$ Million	73	32	44	41	15
Erosion Damage Reduction	$ Million	10.6	2.4	23	8.2	1
Wildfire Damage Reduction	$ Million	8.5	1.1	13	7.4	1
Irrigation Development	1,000 Acres	200	200	100	--	16
Recreation Development	Million Recreation Days	144	51	35	93	22
Fish and Wildlife Development						
Sport Fishing	Million Man-Days	9.7	9.7	100	0	1
Hunting	Million Man-Days	2.1	2.1	100	0	
Electric Power Development						
Energy	1,000 gigawatt-hours	43	43	100	0	18
Peak Demand	1,000 megawatts	8	8	100	0	3

1/ Amount required to meet all obligations of the "Law of the River," Mexican Treaty, losses, and regional

Table 10
RESPONSE TO PROJECTED REQUIREMENTS
rer Colorado Region

se	Remaining Needs	1981-2000 Projected Require-ments	1981-2000 Program Response	1981-2000 Percent Response	1981-2000 Remaining Needs	2001-2020 Projected Require-ments	2001-2020 Program Response	2001-2020 Percent Response	2001-2020 Remaining Needs
	1,485	14,900	14,460	97	440	16,154	15,984	99	170
	--	1,670	1,670	100	--	2,738	2,738	100	--
	41	152	102	67	50	310	242	78	68
	8.2	16.6	9.6	58	7.0	24.1	17.8	74	6.3
	7.4	12.9	3.2	25	9.7	20.0	8.0	40	12.0
	--	168	168	100	--	132	132	100	--
	93	221	119	54	102	307	115	37	192
	0	15.1	15.1	100	0	26.0	26.0	100	0
	0	3.5	3.5	100	0	5.1	5.1	100	0
	0	186	186	100	0	565	565	100	0
	0	36	36	100	0	108	108	100	0

y, losses, and regional consumptive uses.

THE ENVIRONMENT

CHAPTER J - THE ENVIRONMENT

The term "environment" defies brief description since it includes all conditions, circumstances, and influences surrounding and affecting the development and maintenance of mankind as well as all other living organisms. In relation to man, it includes the availability of work for pay, living conditions, safety, recreation opportunities, material goods, services, water, food, and a host of other factors conducive to existence at a given level of quality of life. In relation to all other associated forms of nature, the environment includes the characteristics, condition, and amount of land and water, habitat, vegetal cover, appearance, and the degree of exploitation of these resources by man. The heritage of present-day and long-past peoples of the Region is included within the concept of the environment.

Some aspects of the natural environment are highly sensitive to the slightest permanent change. These have evolved through eons of special conditions which, when upset, quickly succumb or are transmuted. The natural environment of the earth itself is transitional--continually evolving, in long-range trends, from one form to another. Man is but one among many factors in this evolution and he has the capability to accelerate, inhibit, or reverse some environmental trends.

The greatest impact of man on the natural environment has been, and will be, simply his expanding population, attended by increasing demands on the natural resources and living space. For each increment of increased population, there attends an increment of depreciation in the natural environment. Increasing demands of population growth are further compounded by the accelerating technological advances and the desires of an affluent society.

As a matter of choice or preference, some elements of the natural environment must be traded for improvements benefiting the welfare and comfort of man. However, the opportunities to make choices become more scarce with higher population concentrations and intensified developments. Many resources tend to be used beyond the limit of their capability, space becomes limited to fewer uses, and natural environmental quality declines.

Therefore, in the interest of preserving the highest possible quality of environment for future generations, it becomes the obligation of all long-range planning to carefully weigh the impacts of proposed development on the multifaceted environment. The remaining natural resources should be carefully preserved and managed to prolong their availability in the highest possible quality.

Recognizing the impact of man's works on the natural environment, Congress passed a law in 1969 which, in effect, requires all Federal agencies to consider the environmental impact of their activities and recommendations. That law, known as the National Environmental Policy Act of 1969 (Public Law 91-190), establishes a national policy to encourage productive and enjoyable harmony between man and his environment, to promote efforts which will prevent or eliminate damage to the environment and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to preserve the archeological and historical resources. Insofar as practicable, the philosophy of the Act has been used in developing the framework plan.

Socio-economic Aspects

Proper planning in implementation of social and economic programs to prevent development of urban and rural slum areas, and to facilitate renovation of such existing areas, is essential to maintenance and enhancement of the environment. Positive action in planning and implementation of programs through effective use of zoning, taxation, finance, and the like are important elements contained in the framework plan.

Water Supply and Quality

An adequate water supply of acceptable quality is a basic requisite to implementation of many of the Region's environmental programs. The maintenance of good water quality in the Colorado River and its tributaries is essential to the recreation, fish and wildlife, and the overall ecology of this major river system. Until adequate water supplies are provided by imports, the Region's water deficiency will increase. Therefore, many water needs will remain unsatisfied and some deterioration of the environment related to water is inevitable. Choices must continue to be made as to the uses of the limited water supply that would best serve regional objectives. These choices will become more difficult as water deficiencies increase. Economic efficiency alone is not an adequate measure by which to make these choices and other factors such as the long-range environmental consequences must be evaluated.

The early action program, consisting largely of the ongoing program, reflects the choices already made in the Region to minimize the adverse effects of a deficient water supply. However, the inadequacy of existing water supplies makes it mandatory that some sacrifices must continue to be made.

The continued excessive overdraft of ground water, which is inevitable until an import water supply is available, also has long-range environmental consequences. The resultant land subsidence disrupts natural drainage, causes damage to structures, and may result in irreparable damage to the physical properties of the evacuated aquifers.

The degradation of the quality of ground and surface waters has adverse environmental and ecological effects. The major water quality problem in the Region is the ever-increasing salinity of the water caused primarily by the concentration of salts due to intensive use and recycling of available supplies. The framework program includes the treatment of water from some naturally saline sources and other salinity control measures.

Land Treatment and Management

The protection of the Region's land resources provides primary support for many of the Region's environmental objectives. The program provides for reduction of damage to the land by erosion and sedimentation, the maintenance or enhancement of grazing capacity which, in turn, provides food and cover for wildlife; and wildfire prevention which protects recreation, fish and wildlife, and esthetic values. Implementation of the framework program would minimize irreversible losses of the land and preserve the freedom of choice for the future resource users.

Flood Control

The protection of the Region's land resources and property from flood damage, as provided by the flood control program, is a primary environmental objective. Flood damage to the land resources is an irreversible loss that is detrimental to fish, wildlife, recreation, and esthetic values, and to the general land resource base of the Region. Flood damage to urban centers is also detrimental to the environment and well-being of the people. The portion of the program requiring flood water detention storage, levees, and channel improvements will need to be evaluated on a project basis to minimize adverse effects on the natural environment. Measures provided in the flood control program which would enhance the environment include flood plain building codes, zoning and health regulations, and the purchase of flood plain lands for open space preservation.

Though flood detention reservoirs cause flooding of some wildlife habitat, benefits to wildlife occur by reason of the growth of vegetation within the flood pool areas and the usual presence of some water for wildlife use. Inclusion of permanent storage pools could provide enhancement of sport fisheries.

Irrigation and Drainage

The maintenance of irrigated agriculture in the Region has important environmental implications. New irrigation development proposed in the program would occur mostly on desert lands. Irrigated lands provide food and water for some species of wildlife, and provide a cooler green belt

in the otherwise hot and dry desert environment. Adverse environmental impacts of agricultural practices, such as the use of pesticides and fertilizers, will require continued surveillance. Drainage of marsh lands may produce detrimental effects on certain water-oriented ecological systems.

Municipal and Industrial Water

The users of municipal and industrial water nearly always have the ability to pay whatever cost is necessary to divert water from other uses, thus, in the competitive situation, it is difficult to implement environmental objectives requiring a water resource base. Major setbacks would likely occur in such programs as fish and wildlife, recreation, scenic, and wild rivers. Water is also necessary to maintain the quality of environment in cities where the welfare of the people ranks highest in priority of consideration. Green lawns, trees, parks, and swimming pools are of even greater importance in the desert environment of the Southwest than in more humid areas. Until an imported water supply is available, the transfer of water from other uses is probable and adverse effects on less essential activities must be anticipated. The facilities provided by the framework program to supply municipal and industrial water present negligible conflict with desirable environmental qualities and, in many instances, such facilities will enhance the environment.

Mineral Resources

Utilization of the mineral resources of the Region is necessary for the well-being of the people of the Nation. The Region supplies about 60 percent of the Nation's copper and significant quantities of other minerals. Continued exploration and development are necessary if the Region is to continue to supply its share of the national demand. Continued vigilance will be necessary to minimize air and water pollution, scarring of the landscape, and other environmental degradation.

Recreation

The preservation of high quality recreational environment is one of the primary concerns in the recreation program. Much of the recreation program is dependent on implementation of other elements of the framework program, especially water supply and water quality. The recreation program provides for a wide range of recreational opportunities which will upgrade the quality of living in the Region.

The acquisition, preservation, and management of lands for recreational use range from urban parks to primitive and wilderness areas. Preservation features of the program include archeological and historical values, natural areas, ecology, wild and scenic rivers, and wilderness areas.

Heritage

The archeological and early historic resources of the Region may be affected both by the developments proposed in the plan and by the pressures for land development brought on by increased population. If the heritage of man's presence in the Region for over 11,000 years is to be preserved, then a systematic, regionwide investigation of these resources and salvage of those that will be destroyed will be necessary.

Fish and Wildlife

The fish and wildlife program outlined herein satisfies the demands for fish and wildlife resources through the year 2020. The program provides for the preservation and improvement of the most productive and unique fish and wildlife habitats, and the acceleration of developments to improve wildlife production throughout the Region.

With the projected rise in human population attended by increased development and human pressure on the natural resource, it is increasingly important that well-planned management programs be strongly supported by all construction, land management, and fish and wildlife agencies to maintain the quality of the natural environment and the associated wildlife populations.

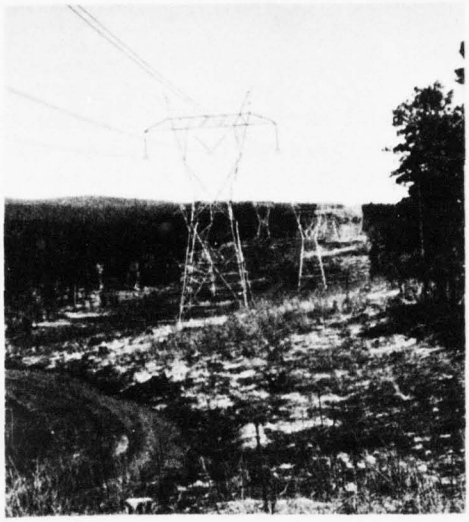
Electric Power

Electric power is a basic necessity to the well-being of the people and to the environment of the Region. Environmental aspects requiring electric energy include air conditioning, to temper otherwise uncomfortable summer temperatures; pumps, to deliver a major portion of the Region's present and future water supply; industrial smog control devices, as well as other air and water pollution control devices; urban street lighting; and lighting to allow increased utilization of urban park facilities.

The regional program provides for the projected future electric power requirements through imports, fossil-fuel thermal plants, nuclear-fuel thermal plants, and pumped storage hydroplants. Cooling towers are utilized and no water would be discharged back to the streams. Surveillance and control of thermal and nuclear pollution will be necessary.

Further consideration should be given to the various alternatives available to meet future power demands and the relative impact of these alternatives on the environmental system.

The siting of thermal electric power plants will take into consideration the effects on air and water pollution. The location of transmission facilities will require careful selection to minimize adverse effects on esthetical, ecological, and recreational aspects of the local environment.



Contrasting methods illustrate how impact on esthetics can be minimized by selective cutting (below), as opposed to clearing (above).

NATURE AND EXTENT OF FUTURE STUDIES

CHAPTER K - NATURE AND EXTENT OF FUTURE STUDIES

Water Supply Studies

Previous water related developments in the Region have concentrated on satisfying immediate problems. The struggle to live with deficient water supplies has often overshadowed other considerations. There has been constant and fierce competition for the available water among the expanding cities, agriculture, the mineral industry, and the fish, wildlife, and recreational interests. Recently, the public interest has broadened to include a greater consideration of the social and environmental aspects.

To best serve the well-being of the greatest number of people, the future planning and development of water and related land resources must study all alternatives and evaluate all water related activities. Elements to be considered include: water quality; enhancement of fish and wildlife; protection and enhancement of areas of historical, scenic, or unique ecological values; and other environmental factors. To achieve this aim, improved methods will be required for evaluation of the environmental aspects and to establish the relative merits of alternative development opportunities. Planning emphasis should be oriented to comprehensive resource development and to the preservation and enhancement of natural resources.

The development of state water plans has been undertaken by the States of the Region. These studies and the framework studies have supplemented each other. As the development of the state water plans advance, a close working relationship with future Federal planning programs should continue so that they are interrelated to best serve the interests of the Region.

The Western United States Water Plan Study, as provided for in Title II of Public Law 90-537, Colorado River Basin Project Act, is a vehicle for the continued broad comprehensive water resource planning to forestall the impending water crisis in the West. The Act provides for a final reconnaissance report to be submitted on or before June 30, 1977.

Of primary importance to the Lower Colorado Region during the 1965 to 1980 period are detailed studies of the means by which the Region's water supplies may be augmented. The studies should be in sufficient detail to provide a basis for project authorization. The early action program should include: (1) studies of the effects of ground-water overdraft in the critical areas and the extent of irreversible damages to be expected if overdraft continues; (2) investigation of ground-water

basins outside the present critical areas as possible interim sources of water that might be conveyed to areas of need; and (3) investigation of the possibility that some irrigated agriculture will be displaced by urban development or by depletion of ground-water supplies to outlying ground-water basins. Since development costs would undoubtedly be high, assurance would be needed as to the long-term yield of these basins and the prospects for capital recovery. Studies should be continued in the fields of reuse of water, precipitation management, and evaporation suppression. Although these augmentation means are not expected to offer a large potential for solving the Region's water problems, they could help reduce importation requirements and provide an interim water supply until an imported water supply can be made available.

Studies of the technical problems associated with the importation of water to the Region should be initiated immediately. Existing legislation will, for all practical purposes, limit these studies to desalination until the year 1978. More reliable data are needed for estimating cost of desalting water in the large quantities that would be necessary to satisfy projected regional water requirements. A prototype desalting plant of much larger capacity than those presently in operation could provide the needed data. Potential plant sites, conveyance routes, and water exchange schemes should be investigated in considerable detail.

An inventory is needed of the sources, quality, and sufficiency of water supplies available for use by the small rural communities of the Region.

Water Quality Studies

Studies of the quality of the ground water from aquifers in the Gila Subregion are of particular importance. The exceptionally efficient use of water in the Subregion allows only insignificant outflows from the area. Due to the nondegradability of the salts present in the natural water supplies, the progressive concentration of salts is perpetuated and ground-water quality is degraded. Studies should determine the rate of quality degradation to be anticipated with the projected rates of ground-water overdraft and with augmentation programs of variable scope. Alternative solutions to the degradation problem should be evaluated. Additional studies are also needed of alternative means of waste water treatment and to provide for the most efficient reuse of reclaimed water. Evaluation of the anticipated degradation of water quality in the Colorado River and how an imported water supply could best be managed to alleviate this degradation are also needed.

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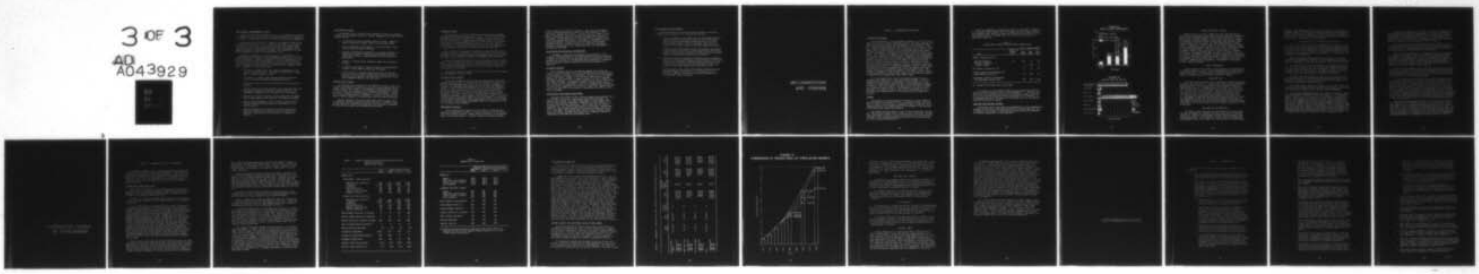

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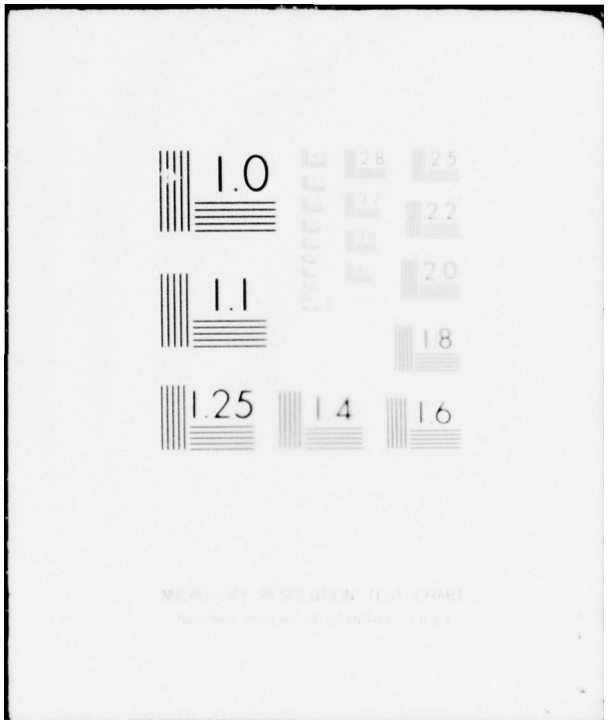
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Land Treatment and Management Studies

Studies to refine the information on the current watershed conditions, soil types, erosion susceptibility, sediment yield rates, and contribution to salinity in streams are essential to effective planning and management.

River basin studies of Type IV intensity are needed to identify and evaluate individual projects in such areas as the Santa Cruz-San Pedro River Basins, and the Salt, Verde, Gila, and Agua Fria drainage areas. Similar studies are needed along those major river flood plains having riparian vegetation to determine the impact of and potential for a vegetative management program for increased water yield.

Research is essential to provide direction for installation of a complete watershed and land resource management program which will assure maximized benefits. Research is needed not only for investigations into the specific factors affecting management of each individual resource, but also needs to be aimed at the various combinations of products and values to determine their interactions before and after management treatments. Examples of research needs are:

1. The effects of water yield from vegetative management within specific vegetative types. Evaluate the impact of this treatment on other multiple-use values.

2. The effects on surface supply and ground-water recharge of runoff control and floodwater retarding structures.

3. Improve snow data collection techniques and runoff prediction formulas.

4. Develop more selective and acceptable pesticides and herbicides and better define the limitations of those presently used. Alternative management tools need additional investigation.

5. The effects of man's activities and land treatment and management on associated fish and wildlife, both game and nongame.

6. Improve timber management systems, develop superior genetic strains of timber, and find more efficient methods to use forest products.

7. Improve techniques for inventorying resources, measuring resource conditions, and organizing resource data for more meaningful interpretation and utilization in management decisions.

Flood Control Studies

The magnitude of the flood problem indicates the need for a research program for flood damage reduction. Specific suggestions for more detailed studies include:

1. The problem of urban hydrology should be studied. Because of rapid urbanization, greater runoff occurs in these areas.

2. Since a large part of the Region is in an arid area, a study should be made of desert hydrology.

3. Research to determine the potential for storing floodwater in underground reservoirs created by nuclear devices and the fracturing of rocks to create greater infiltration rates of percolation.

4. Research to develop better hydrologic models for flood forecasting.

5. To improve flood warning system by research in precipitation forecast through radar sounding and other means.

6. Further studies to evaluate alternative means of obtaining flood protection in specific areas should include, but not be limited to, environmental considerations, nonstructural flood plain management measures, and open space.

Electric Power Studies

The projected large increases in the demand for electric power will require investigations to determine the most suitable locations for the thermal electric power plants. Environmental considerations and availability of water for cooling will be of primary consideration. Thermal pollution is presently avoided through use of cooling towers. The use of dry-cooling towers should be evaluated in terms of the value of the water conserved compared to the additional cost that would be entailed.

Specific reaches of rivers and flood plains having unusual scenic or ecological qualities, and other areas of historic or esthetic significance, need to be identified so that they can be avoided in planning for electric power plants and transmission facilities.

Recreation Studies

Further studies should be undertaken to determine and implement Federal and state land use goals and policies. Identification of land and water available and suitable for recreation purposes should be a part of such studies. In addition, the recreation land classification system should be reevaluated and improved to provide a more efficient technique for identifying recreation resources. Land use planning should take into consideration the need to preserve unique natural and cultural features before such resources are lost to other uses.

New techniques for measuring recreation use and recreation user preference should be researched. These new techniques should be readily available to all recreation planners and management agencies and should encourage uniformity among all agencies in amassing statistical data.

Detailed recreation studies for the Gila Subregion should be undertaken. These studies should lead to delineating agency roles in providing recreation opportunity, specific facility development plans, and providing alternative opportunity options where recreation opportunity is precluded by constraints.

Studies are needed to determine the most feasible method for banking and disseminating recreation data.

Fish and Wildlife Studies

Studies are needed to determine habitat requirements of game and nongame species of fish and wildlife, and to determine how man's activities and land management practices affect the habitat requirements of wildlife, including game and nongame species and rare and endangered species. There is need for information on ways of establishing palatable browse and other vegetation to increase wildlife populations. Ecological characteristics such as water temperature, toxin content, turbidity, pool ripple relationships, stream bottom characteristics, streamside vegetation, and biological characteristics need to be studied. Existing habitat improvement methods and the development of new methods such as aquatic weed control, water impoundments with artificial stream construction, and phreatophyte management studies are needed to provide for increasing fishing demands.

Environmental Research

A more comprehensive evaluation of the effects of regional water planning and management programs in terms of productive utilization of labor and capital is needed. Though economic efficiency is an important guide to the implementation of a water resources development program,

other objectives must also be considered. The Region, for example, contains underdeveloped areas, areas of economic depression, and, in many cases, immobile work forces. Providing jobs and income to residents of these areas should be considered an important objective of the Region. Projections point to the concentration of population in a few large metropolitan centers in the Region, consequences of which should be explored. Studies which form the basis for evaluating alternative courses of action to meet such objectives, therefore, become an integral part of the comprehensive plan for development of the Region's resources.

Archeological and Historical Investigations

A systematic, Regionwide investigation and assessment of the character and significance of the archeological and historic resources is needed as the basis for deciding what should be preserved for future generations, what should be investigated and salvaged prior to destruction by project activities, and which sites may be allowed to be destroyed.

Ecological Research

Some threatened natural environmental damages are obvious and dramatic, and have already caused some important water-oriented projects to be abandoned, relocated, or redesigned. The more subtle, and perhaps equally significant, changes in the ecological spectrum have not been addressed or even recognized, in many instances, for lack of manpower and expert knowledge. A more detailed and precise picture of the ecological effects of water development is needed. Greater sophistication must be achieved to insure that the less obvious damages are avoided and the less obvious enhancements are achieved. Impacts far removed from the project area must also be considered in evaluating their effects on the total environment.

Hydroclimatic Data Networks Requirement

The nature and extent of basic data requirements are dependent upon the logistics involved in a particular study being undertaken. In general, most studies will require measurement of hydroclimatic data such as precipitation, temperature, evaporation, solar radiation, soil moisture, and snow water equivalent. Various water and air quality parameters will also require observations or monitoring. Existing networks will require rapid expansion and funding for proper quality control of the data. The required basic data of various Federal, State, local, and private programs should envision an integrated network for observing or monitoring the environmental data.

Socio-economic Analyses Needed

Several additional socio-economic analyses needed to extend and supplement those included in this study are as follows:

1. Additional analyses on how water resource development programs change employment participation rates, types of employment, income distribution patterns, educational levels, or other socio-economic factors should be initiated, particularly as related to low income, minority, and rural population sectors.

2. Studies should be initiated to assess the economic consequences of deteriorating water quality upon industrial and agricultural output in terms of how it affects the level and rate of regional economic growth and the well-being of the people.

3. Additional sensitivity analyses of alternatives and assumptions should be conducted, particularly as they pertain to efficiencies of water use, alternative cropping patterns, alternative crop yields, level of water availability predicated on 1965 conditions, and other agricultural production possibilities.

4. Studies exploring the relationships between economic activity and environmental characteristics of the Region should be initiated. Methods to measure environmental parameters in socio-economic terms are needed.

IMPLEMENTATION AND FUNDING

CHAPTER L - IMPLEMENTATION AND FUNDING

Initiating the Program

The implementation of the development program to fulfill the future needs of the Region requires immediate action to accelerate programs for water resources and related land development by over threefold. Most of the early action programs are continuations of those currently underway. Though the Region has had one of the fastest growth rates in the Nation, and is one of the most critical water deficient areas, water resource development has progressed more slowly than that of most other areas. This slowness of response to the needs can be attributed largely to the sheer complexity of the problems, the magnitude of developments necessary to solve them, and the legal problems which have retarded the Region's ability to fully utilize its share of Colorado River water. While the latter has been partially resolved by authorized projects, the others such as funding continue to obstruct the Region's efforts to meet its present needs or to implement programs to satisfy future needs. Consequently, the action programs have fallen far behind, resulting in the accumulation of a tremendous backlog of development needs. The timing of a program of water importation to the Region is most critical because implementation of many other elements of the framework program is dependent on an adequate and timely water supply.

It is anticipated that a public information program will be a necessary and integral part of the early action program. It will be imperative that the public be made aware of the problems and of the foreseeable consequences created thereby; that all potentially feasible solutions be fully considered by the public; and that time be allowed for formation of public opinion. Determination of the public desire and public willingness to pay the cost of new developments must be effected before implementation of the proposed action program can be achieved.

Funding

The funding of existing programs would need to be accelerated by over threefold if all elements are to be completed by 1980. The $720 million Central Arizona Project, representing nearly 50 percent of the Federal portion of the regional early action program, is the principal authorized project needing acceleration.

The funding schedule needed to catch up with the Region's development needs has been spread over a 35-year period to year 2000. At that time, the Region's backlog of needs would essentially be satisfied and the 2000 to 2020 funding program would need only to satisfy the needs arising during that 20-year period.

Table 11, graphically illustrated in Figure 19, provides a comparison of the present annual average level of funding with that needed in each of the subsequent time frames to achieve the water and related land resources development program. Estimated total cost, 1965-2020 by purposes, is depicted by Figure 20.

Table 11
Average Annual Federal and Non-Federal Program Costs

Unit: Million Dollars

Item	Present 1/ Funding Level	1965-1980	1981-2000	2001-2020
Federal Installation Costs				
Regional Programs	30	100	97	205
National Obligation, Mexican Treaty		--	163	--
Non-Federal Installation Cost		36	56	86
Federal Operation, Maintenance, and Replacement Annual Costs		66	290	359
Non-Federal Operation, Maintenance, and Replacement Annual Costs		108	548	1,499

1/ Average for the years 1965 through 1969.

The division of costs between Federal and non-Federal interests was based on present legal and institutional arrangements. It has been indicated that the non-Federal portion of the recreation program could probably not be achieved unless the Federal participation is increased. It is estimated that about 70 percent of the Federal costs for the regional framework plan would be repaid.

Legal and Institutional Problems

Constraints, which could delay the implementation of the comprehensive program, include some of the existing policies of Federal agencies, lack of authority on the part of state and local agencies, and the constraint of financial capabilities of local agencies.

FIGURE 19
ANNUAL FUNDING REQUIREMENTS

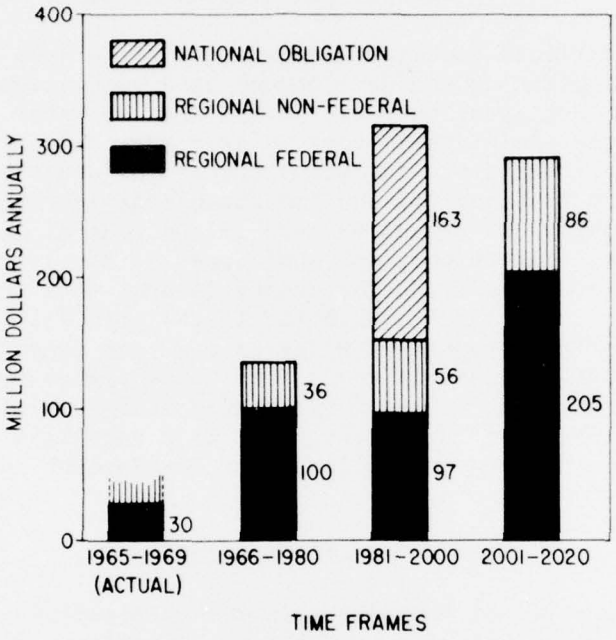
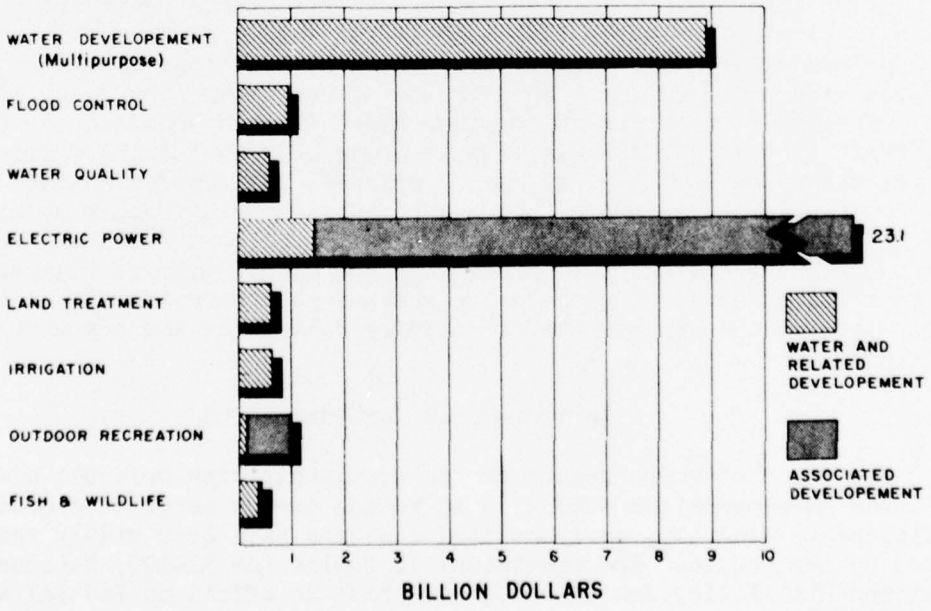


FIGURE 20
ESTIMATED TOTAL COST 1965-2020



Federal-State Water Problems

Though conflicts do exist, Federal and state laws applying to water resource planning and development have been largely complementary. Tensions have developed, however, in the area of water law. Though historically the administration of water rights has been left largely to the states, there are a number of provisions under Federal constitutional powers that have placed the state administration of water rights in jeopardy. A recent concern is the Federal grouping of water uses on Indian reservations, national forests, etc., under the category of "reserved water rights." The theory is that when the Federal Government creates a land reservation in the arid West, it reserves such amounts of unappropriated water as might be necessary to utilize the land for the purposes intended. As these rights are not quantified, this theory creates an uncertainty, making it impossible for the states to integrate them with private rights. This uncertainty as to the amounts of remaining water available for development is detrimental to water resource planning.

State Institutions

A major problem of the states is the multiplicity of organizations involved with water resources. These organizations are often overlapping and unrelated. A centralization of responsibility within the states for matters dealing with water resources is needed.

State Water Law

State laws prescribing the steps to perfecting a water right appropriation usually include: (1) a notice of intent or an application to appropriate water; (2) the building of works necessary to divert or impound water; and (3) the application of the water to a beneficial use. The priority of the state water right is then based on the rule of "First in time is first in right." However, laws of the various states differ as to (1) what may be defined as a beneficial use; (2) what priority or preference may be applied to different uses; (3) the amount of water per acre that may be allowed under an irrigation appropriation; and (4) procedures for acquisition of rights. Consideration should be given as to whether greater uniformity between water laws of the various states would be desirable, and how this could be achieved.

Environmental Considerations

The field of water resources has previously been oriented toward resource development as evaluated in rather narrow terms of economic efficiency. Recently, environmental concepts have been widely recognized by the public. The provisions of Public Law 91-190, National Environmental Policy Act of 1969, will have an effect on Federal water

resources development programs since this law requires that the environmental impact of potential developments be analyzed. New methods of evaluation are needed to properly account for the new environmental concepts. Without doubt, further state and Federal legislation governing environmental considerations will be enacted.

Recommendations of Framework Study Work Groups

During the course of the study, recommendations relating to legal and institutional changes needed to satisfy particular interests were developed in the various appendixes. Though these recommendations have not been endorsed by the Legal and Institutional Work Group, they are presented in the Legal and Institutional Appendix. Following are some of the major recommendations:

Land Use and Watershed Management--Implementation of the land treatment and management program will require increased state participation in management of watershed areas where state lands are involved.

Additional Federal and state financing and assistance are needed for: (1) installation of all land treatment and management measures, including those for improvement of the quantity, quality, and timing of water yields; and (2) storage in floodwater retarding structures to provide low flow augmentation for improved water quality.

Accelerate land use planning for areas which are expected to be developed for urban use and implement effective and equitable taxing and zoning ordinances in order to direct potential developments in an orderly and esthetically pleasing fashion.

The system by which grazing privileges on public owned lands are tied to private holdings should be reviewed periodically to insure that the system is both equitable and conducive to good management.

Flood Control--Enabling legislation by states is needed to control the use and proper development of the flood plains. Such legislation should include, but not be limited to, the following: recognition by states of the overall responsibility of flood plain regulations as a part of flood damage reduction for the health, safety, and welfare of its citizens; adoption of statewide minimum standards for flood plain regulations; state assistance in providing technical information; state aid for acquisition of land for future projects or for preservation of open space; and state adoption of flood plain regulations based on its minimum standards for those areas where local units of government have not adopted state approved regulations within a reasonable time.

Irrigation and Drainage--The "160-acre limitation" reclamation law, long recognized as uneconomic in many areas, is becoming increasingly questionable under price-cost pressures facing irrigated agriculture in recent years. Consideration should be given to substituting for this "160-acre limitation" provision in reclamation law, an "acre-limitation" based on a productivity classification of project lands.

Other problems facing irrigated agriculture are changes in water law establishing "priorities of use." The conversion of irrigation water to other uses could create many problems for the irrigation interests, for urban areas, and for state and local governments.

Recreation--Implementation of the framework program for recreation will require legislation to amend existing statutes governing Federal participation in recreational activities; to establish new statutes providing for Federal funding; to establish new Federal and state land use policies and goals; and to establish funding and administrative authority relative to beautification, water and sewage treatment facilities, and other water quality control measures.

State legislation needed would include laws establishing state land use policies, recognizing the multiple-use management principle; making state lands available to local entities for recreation uses; enabling and strengthening zoning statutes; and requiring grazing lessees to permit public access for recreational purposes.

Fish and Wildlife--State programs that benefit the general public and include the preservation of wildlife resources for all people must have a broader base for financing than the sportsman's dollar. Other programs that benefit the general public and need general funds are those not directly related to fishing and hunting, such as conservation education, management and research for nongame species, and participation in programs for the preservation of endangered species. In addition, state and Federal legislative and administrative changes are needed to provide the appropriate lands and associated agencies with adequate funds to accelerate programs and to develop fish and wildlife facilities to meet public demands for the use of the fish and wildlife resources.

Water Quality--Water quality problems of the basin are currently being defined by the cooperative efforts of local, state, and Federal participants in the abatement conference proceedings on the Colorado River Basin, under the authority of the Water Quality Act of 1965. The search for solutions to the water quality problems so defined must necessarily extend to an examination of existing legal systems and institutional arrangements to determine their effectiveness in implementing any proposed plan for the management of water quantity and quality.

ALTERNATIVE LEVELS OF DEVELOPMENT

CHAPTER M - ALTERNATIVE LEVELS OF DEVELOPMENT

The previous chapters of this report have dealt exclusively with modified OBE-ERS projected levels of development. These projections were based upon regional review and modifications of the March 1968 projections (OBE-ERS) which were furnished to the Region by the Water Resources Council, and are considered to be in the median range. Additional revisions to the population projections were provided by OBE in June 1969.

OBE-ERS Projections, March 1968

The differences between the OBE-ERS projections for the Region and those used in developing the regional framework program are minor, especially in view of the unpredictable changes in trends that are inherent in any 30- to 50-year projection.

However, the differences between some elements of the projections for the Lower Main Stem and Little Colorado Subregions are of greater significance.

In the Lower Main Stem Subregion, there is a major difference in the population projections of the Nevada portion where the economic growth is largely recreation and tourist oriented. The water-oriented recreational opportunities afforded by Lakes Mead, Mohave, and Havasu on the Colorado River and the increasing popularity of the lavish entertainment facilities of Las Vegas, Nevada, have accounted for a rapidly increasing population growth. The population of Clark County, Nevada, has more than doubled between 1960 and 1970, and the Mohave County, Arizona, population has more than tripled. The land availability, coupled with the water conveyance and treatment facilities now under construction to serve Las Vegas, will probably support a continuation of a high growth rate through year 2000. The difference between the modified OBE-ERS projections and the 1968 OBE-ERS projections for the Lower Main Stem Subregion is largely a matter of timing. The modified projections would require a more rapid rate of water-related development until year 2000, and then a reduced development rate until 2020 as the two projections converge to within 15 percent of each other.

There are also significant percentage differences between the 1968 OBE-ERS and the modified OBE-ERS projections for population and irrigated agriculture in the Little Colorado Subregion after year 2000. However, the numerical differences are not large. The increases are largely in McKinley County, New Mexico, and are attributed to economic advances by Indians, extended development in uranium, anticipated coal development,

and increased employment opportunity caused by anticipated increases in travel along the Interstate Highway System. The projected increases in development of irrigated land in the Little Colorado Subregion is attributable to small new irrigation development on Indian lands in McKinley County, New Mexico.

The most significant increase in land requirements, resulting from the use of the modified OBE-ERS projected level of development for the Region, is for irrigated cropland and urban land. Projected land requirement for livestock grazing is the only use which decreases using the modified projections, and this decrease is minor. The remainder of the land use requirements either remain unchanged or show only slight increases with the modified projections. Using either set of projections (modified or unmodified OBE-ERS), there are sufficient suitable lands for each land use.

The effect of the differences between the two projections on the framework plan is minor. The difference in the water depletion requirements for all uses in the Subregion is only 40,000 acre-feet.

Table 12 summarizes the regional demand for water and related functions and services to satisfy the 1968 OBE-ERS projections. Comparisons of significant elements from the 1968 OBE-ERS projections and modified OBE-ERS projections are shown by percentages on Table 13.

The modified OBE-ERS level of development would result in increases, above that for the OBE-ERS level, in the depletion requirements for the years 1980 and 2020 amounting to 5 percent and 7 percent, respectively. The corresponding increase in the economic final demand for goods and services would be 11 percent, and the labor requirement would be larger by 12 percent in year 1980. By year 2020, the modified projections would be 9 percent greater for economic final demand for goods and services, and labor requirements would be 7 percent greater than with the straight OBE-ERS projections.

The 5 percent difference between the two projections for regional water requirements in 1980 would have no effect on the early action program, but would result in a reduction of ground-water overdraft from the 1.5 million acre-feet associated with the modified OBE-ERS projections to 1.1 million acre-feet. The need for an imported water supply by year 2000 would remain unchanged. The regional portion of the importation could possibly be delayed a few years under the OBE-ERS projections, but a 5-year delay would be about the maximum extent. With the uncertainties of projections 30 years in the future, and the many difficulties inherent in the planning and construction of a project of this magnitude, concern for such minor variance is unjustified at this time. As future studies are made, the projections will be updated periodically according to the most recent trends.

Table 12 - Demand for Water and Related Functions and Services
OBE-ERS Projections
Lower Colorado Region

	1965 Base	Total Annual Demand 1980	2000	2020
WATER SUPPLY				
Withdrawals (1,000 Acre-Feet)				
Municipal and Industrial	450	750	1,447	2,588
Irrigation	9,138	8,922	7,843	7,754
Recreation	11	20	39	68
Fish and Wildlife	196	209	301	531
Electric Power Cooling	10	37	106	435
Mineral Production	105	169	250	327
Depletions (1,000 Acre-Feet)				
Municipal and Industrial	198	319	591	1,084
Irrigation	4,626	5,698	4,903	4,965
Recreation	4	7	13	23
Fish and Wildlife	110	138	212	387
Electric Power Cooling	10	37	106	435
Mineral Production	52	84	124	160
Flood Damage Prevention ($ Million)	41	71	143	298
Erosion Damage Reduction ($ Million)	7	11	17	24
Outdoor Recreation (Million Rec-days)	138	256	503	888
Sport Fishing (Million Man-days)	4	9	13	23
Hunting (Million Man-days)	1.3	1.9	3.1	4.8
Irrigation Development	1,315	124	118	134
Irrigation System Rehabilitation	293	429	0	0
Drainage (1,000 Acres)	212	68	32	88
Electric Power (Billion KWH)	13.3	43.4	186.1	564.5
Electric Power (Million KW)	2.7	8.3	35.8	108.5

Table 13
Comparison of Projections

	Modified 1968 OBE-ERS Projections as Percent of 1968 OBE-ERS Projections		
	1980	2000	2020
Population			
Region	110.1	111.9	105.2
Lower Main Stem Subregion	146.6	148.5	115.1
Little Colorado Subregion	101.9	109.5	124.7
Gila Subregion	100.1	100.5	100.3
Irrigated Harvested Acreage			
Region	106	109	109
Lower Main Stem Subregion	113	106	107
Little Colorado Subregion	112	122	132
Gila Subregion	103	110	109
Water Depletion Requirements	105	108	107
Flood Damage Prevention	103	106	104
Erosion Damage Prevention	100	100	100
Outdoor Recreation (rec-days)	105	107	104
Sport Fishing (man-days)	110	115	112
Hunting (man-days)	113	113	113
Electric Power 1/	100	100	100

1/ Power Work Group projections were higher than either OBE-ERS or modified OBE-ERS and were regarded equally substitutive for each of the economic projections.

OBE Projections, June 1969

The Office of Business Economics issued revised population projections in June 1969. The Lower Colorado Region framework study had progressed beyond the point where further changes in projections could be accommodated. However, these projections were examined and found to reflect major differences in projected population growth.

A comparison of the modified OBE population projections, the OBE March 1968 projections, and those issued June 1969 is shown in Table 14, and graphically in Figure 21. As shown in Figure 21, both the 1968 and 1969 OBE projections of the 1980 population indicate a substantial decline in rate of growth between 1970 and 1980, then increasing again after 1980. The projections issued in June 1969 would indicate a slower rate of growth in the next 10-year period than has occurred in any 10-year period since 1940, and that the 1970 to 1980 rate would be only 50 percent of the 1960 to 1970 rate. This seems unreasonable in view of the 1970 census data which ranks Nevada and Arizona first and second, respectively, among the states in rate of growth over the past 10 years. In Clark County, containing most of Nevada's share of the Lower Colorado Region population, the 1970 census count was 112 percent above that of 1960, with population increasing from 127,000 to 270,000. Arizona showed an increase of 35 percent, with the population increasing from 1,302,161 in 1960 to 1,752,122 in 1970. The Region's total population increase from 1960 to 1970 was 42 percent. The growth rate of the Region would need to slow to 17 percent for the next 10-year period to stay within the June 1969 projections. The discrepancy is greatest in the Lower Main Stem Subregion which has been experiencing a recent growth boom centered largely in the recreation, retirement, and entertainment sectors. The 1960 to 1970 population growth rate of 80 percent would need to slow to 13 percent for the next 10-year period to stay within the June 1969 projections for the Lower Main Stem Subregion.

Economic Analysis of Alternative Levels of Water Supply

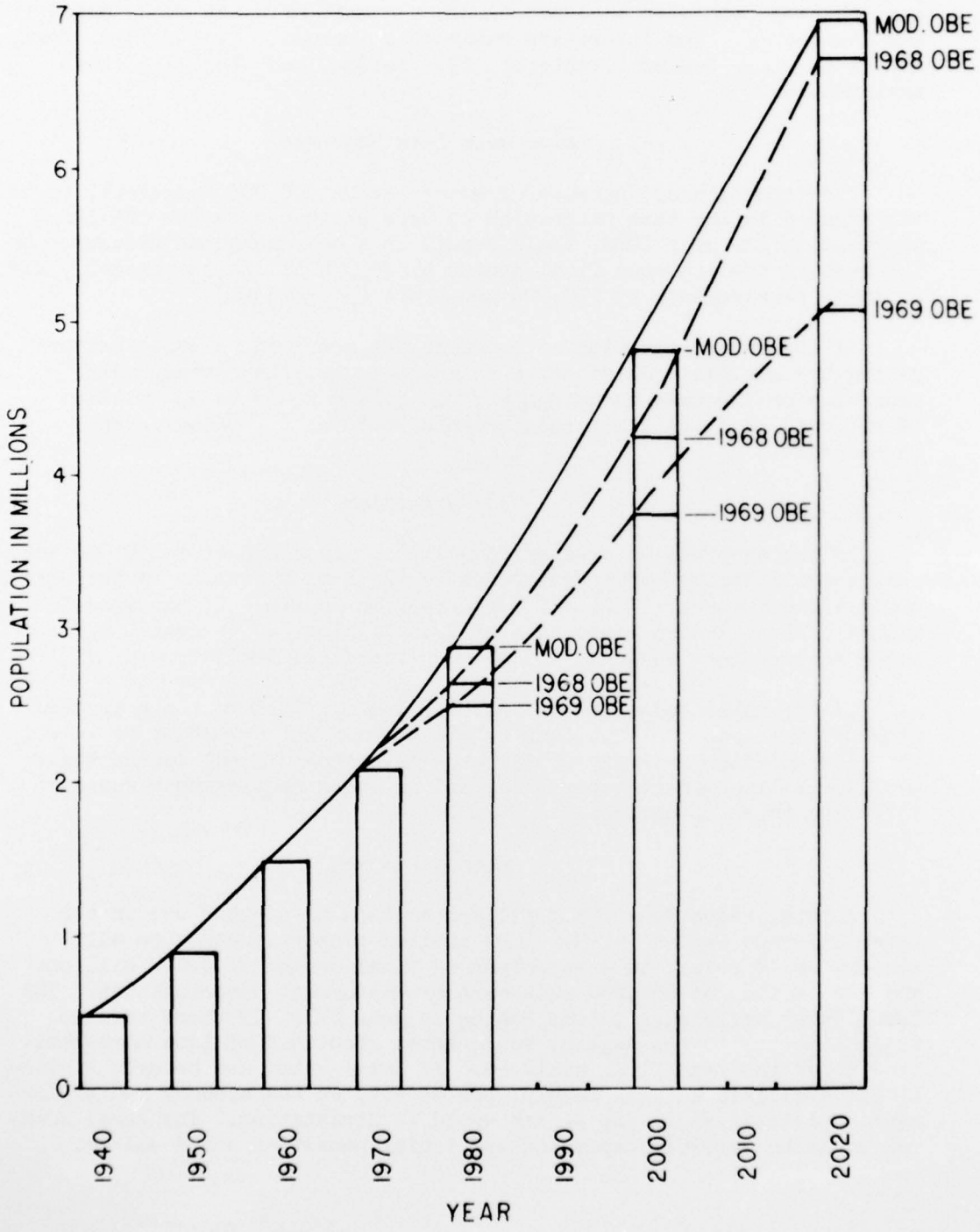
An analysis was made to evaluate the economic significance of increasing or decreasing the level of water availability as compared with the annual requirements computed by use of the OBE-ERS projections for year 2020. A value of plus or minus 500,000 acre-feet was used in the analysis for the Lower Main Stem Subregion, and plus or minus 1,000,000 acre-feet for the Gila Subregion. A similar analysis for the Little Colorado Subregion would yield insignificant effects.

Two alternative projections were made for each of the two subregions using the increased level of water availability, and two also at the decreased level using two sets of assumptions. The first set of alternatives postulated that the assumed increase or decrease in water

Table 14 - Comparison of Modified OBE, March 1968, and June 1969 OBE Population Projections

	1960 Census	1970 Census	Percent Growth 1960-1970	1980 Projection	Projected Percent Growth 1970-1980	2000 Projection	2020 Projection
Lower Colorado Region	1,505,522	2,132,584	42				
Modified OBE				2,910,600	36	4,796,700	6,983,100
1968 OBE				2,644,137	24	4,263,150	6,639,165
1969 OBE				2,495,596	17	3,749,874	5,084,297
Lower Main Stem	235,546	424,524	80				
Modified OBE				815,600	92	1,519,700	2,020,500
1968 OBE				526,146	24	1,023,192	1,756,024
1969 OBE				479,300	13	751,800	1,018,900
Little Colorado	105,641	123,221	17				
Modified OBE				183,500	49	240,400	326,400
1968 OBE				180,000	46	219,600	261,700
1969 OBE				180,500	47	212,900	238,700
Gila	1,164,335	1,584,839	36				
Modified OBE				1,911,500	21	3,036,600	4,636,200
1968 OBE				1,907,900	20	3,020,400	4,621,500
1969 OBE				1,835,800	16	2,785,200	3,826,700

FIGURE 21
COMPARISON OF PROJECTIONS OF POPULATION GROWTH



availability would be shared proportionately by all water users. The second set of alternatives was based on the hypothesis that the increase or decrease in water availability would affect only those water uses contributing the least economic return per unit of water used, directly and indirectly. The low-return water uses include: (1) forage, feed, and food; (2) feeder livestock; (3) cotton; and (4) all other agriculture.

Lower Main Stem Subregion

The reduction or increase of water use by 500,000 acre-feet, to be distributed in the same proportion as uses projected in the OBE-ERS projections for year 2020, would result in a corresponding reduction or increase in the economic final demand by $6.8 billion (33 percent), and in labor requirements by 220,000 man-years (34 percent).

If the water reduction or increase was confined to those sectors making the smallest contribution to the economy, the corresponding reduction or increase in economic final demand would be $86 million (4 percent), and the labor requirements would be 2,100 man-years (3 percent).

Gila Subregion

In the analysis of a water reduction or increase of 1,000,000 acre-feet to be distributed in proportion to the uses projected in the OBE-ERS projections for year 2020, the corresponding increase or decrease in economic final demand would be over $9.9 billion (24 percent), and for labor requirements would be 394,000 man-years (24 percent).

If the water reduction or increase was confined to those sectors with the smallest contributions to the economy per acre-foot of water, the corresponding decrease or increase in economic final demand would be $175 million (about 4 percent), and in labor requirements would be 5,700 man-years (3 percent).

Regional Impact

A total reduction of 1.5 million acre-feet in water use in the Lower Colorado Region in year 2020 applied proportionately to all sectors would result in a reduction in final demand of $16.7 billion, and a reduction of 614,000 man-years of employment opportunities. The total water deficiency in the Region in year 2020, if there were no water imported to the Region, would total about 4.5 million acre-feet, or 3 times the reductions analyzed. If total water use becomes limited to the available natural supply, the effects on the economy and employment opportunities in the Region would be devastating. The rural economy would be severely depressed and social penalties would spiral.

The apparent minimum impact on the Region's economy would occur if the reduction in water usage were applied to the agricultural sectors. This analysis, considering factors of regional economic efficiency, provides only one of several studies needed to assist the Region in making future choices in the utilization of its water resources. Another important consideration in this time of social unrest is that a portion of the labor force in the agricultural sectors is unskilled and has but little potential for retraining. Whether the Region's interests are best served by accepting the trend toward reduction of unskilled job opportunities and the resultant social impacts would need to be considered. Some additional factors which would occur because of a reduced water supply and which need to be analyzed are: the effect on local and state tax base of retiring productive lands, the effect on rural communities of reducing their economic base and employment opportunities, the inevitable further population shift from rural to urban centers and the resultant increase in urban social problems, the effect on farm and irrigation district operations and revenue, loss of both private and public capital improvements, the increased demands for social services in primarily rural counties, and the effect on the national food and fiber requirements.

It is very unlikely that major reductions in water usage in selective agricultural sectors could be achieved directly by regional choice because legal and institutional constraints, especially in the field of water rights, would preclude such a direct transfer of water usage. Without a water importation program, such a reduction could occur naturally due to economic pressures, or due to exhaustion of the ground-water resources. In this event, ground-water pumping would continue until the dropping water level made further operations uneconomical for some agricultural uses, or until the source was exhausted.

RECOMMENDATIONS

CHAPTER N - RECOMMENDATIONS

The Lower Colorado Region State-Federal Interagency Group recommends:

1. That the framework program presented in the Main Report be used as a general guide for the future development of water and related land resources of the Lower Colorado Region.

2. That priority of action be directed to the current backlog of critical needs, plus those expected by 1980, to satisfy requirements for water conservation and supply; water quality improvements; rehabilitation of irrigation systems; land treatment and management; flood control; fish and wildlife enhancement; outdoor recreation; the enhancement, conservation, and preservation of environmental values; and public well-being. Critical program needs recommended for early consideration are:

   a. That funding for the Central Arizona Project be accelerated for completion of the project by 1980 to alleviate the present critical water deficiencies.

   b. That studies of Type IV intensity be initiated in such areas as the Santa Cruz-San Pedro River Basin, Whitewater Draw, and Willcox Playa to identify and evaluate individual projects for water and related land resource development. Similar studies are needed in the Salt, Verde, Gila, and Agua Fria drainage areas and along those major streams with riparian vegetation to determine impact of and potential for a vegetation management program for increased water yield.

   c. That presently authorized watershed projects be completed in time to, as nearly as possible, meet the 1980 needs, with special emphasis on those projects that are related to other water resource developments.

   d. That prompt and effective joint action be taken to accelerate programs for erosion, sediment, and runoff control; irrigation, including water management systems and impervious lining of distribution systems; and drainage to more effectively utilize and preserve the productive capacity of the Region's water and related land resource base.

e. That construction of presently authorized flood control improvements be implemented as rapidly as funds and satisfactory local cooperation can be made available. This acceleration is essential to partially alleviate the 1980 needs and the growing flood damage potential as the area becomes urbanized, to minimize disruptions to normal pursuits, to prevent increasing possibilities of loss of life and property, and to generally improve the well-being of the people of the Region.

f. That flood plain information studies and effective flood plain management programs be accelerated to avoid potential flood damages.

g. That improved evaluation procedures be established for measuring the impacts of water and related land resource developments on esthetic, ecologic, public health, fish and wildlife, and other environmental aspects. A better measurement of these intangible effects is needed to more accurately weigh the relative merits of alternative development opportunities.

h. That Federal, state, and local agencies should monitor, coordinate, participate in, and support early completion of the Western United States Water Plan studies, especially those studies pertaining to importation of water to the Colorado River by 1990. Such importation should include the water required to satisfy the United States' obligation for delivery of water to Mexico under the Mexican Water Treaty, thereby relieving the States of the Colorado River Basin of the burden of meeting this obligation.

i. That implementation of an effective salinity control program in the Colorado River Basin be given high priority. Because salinity control in the Upper Colorado Region has a major effect on the salinity in the lower Colorado River, support should be given for a basinwide salinity control program.

j. That studies of the quality of ground water in the Gila Subregion be intensified to determine the rate of degradation with continuation of current water-use practices, the effects of augmentation programs, and the effects of alternative solutions to ground-water degradation.

k. That present studies be accelerated to locate potential power sources, to determine locations for electric power plants and transmission facilities, and to devise new technologies for minimizing adverse environmental effects.

l. That the 12 rivers in the Region, identified for possible designation as Wild and Scenic Rivers on maps following page 62, be investigated at the earliest possible date to determine whether the preservation or the development of these rivers is in the best interest of the Region and the Nation.

m. That effective land-use policy and planning be implemented to insure preservation of open space; unique natural, wildlife, archeological, and historic areas; wild and scenic rivers; and to insure the protection of fish and wildlife, including rare and endangered species.

n. That present legal and institutional arrangements be adjusted to relieve funding constraints and to enable the preservation of adequate outdoor recreation and fish-and-wildlife-oriented opportunities in and around the Region's cities.

3. That the Federal, state, and local agencies concerned with water and related land resource development be adequately staffed and funded to vigorously pursue programs required to attain a level of development that will support the future economic growth and quality-of-living goals.

4. That the well-being of the people be a principal criterion in formulating plans and programs for development of the resources of the Region.

5. That sufficient land area (as shown on map following page 94) and water supply be managed in such a manner as to yield maximum fish and wildlife benefits, but not to the exclusion of other compatible or complementary uses.

6. That studies be initiated and current studies be accelerated for collection of more comprehensive data to better facilitate effective planning of water and related land resource development.

7. That the framework program be continually reviewed, modified, and improved as dictated by changing needs, advances in technology, availability of additional data, and by experience.

8. That the Coordinated Planning Subcommittee of PSIAC be continued on an ad hoc basis, as recommended by the Pacific Southwest Inter-Agency Committee, to provide the coordination needed for updating the Type I Framework Studies and for other planning activities under the guidance of the Water Resources Council.

9. That future studies listed in Chapter K, Nature and Extent of Future Studies, be implemented as rapidly as possible.

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